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Application of Data Steganographic Method in Video Sequences Using Histogram Shifting in the Discrete Wavelet Transform

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Abstract

This research paper presents efficient data steganography method in video sequences based on histogram shifting in discrete wavelet transform (DWT). The proposal DWT-histogram shifting video data steganography depends on applying histogram shifting in DWT. The proposed DWT-histogram shifting video data steganography is reversible and has the capability of embedding three bit per pixel, maximizing the embedding capacity and still preserving good visual quality for stego-video. The data to be hidden is not simply inserted on the wavelet coefficients but using histogram shifting for middle and high frequency bands to offer sufficient embedding room. The performance of the proposed DWT-histogram shifting video data steganography scheme is estimated and compared with existing methods in terms of payload and stego-video quality. The test results demonstrated that the proposed DWT-histogram shifting video data steganography method improved significantly the embedding capacity and still keeping the stego-video quality.

Keywords: DWT, Steganography, Data hiding, multi-resolution, wavelet decomposition.

INTRODUCTION

The unlimited utilization of digital media on the Internet has brought a lot of security concerns regarding the security of such digital media files. Now, video is considered as one of most popular mediums for communication and enjoyment due to easy editing and perfect reproduction. The researchers suggested and enhanced several data embedding schemes, like steganographic, and watermarking schemes [1-4]. Steganography concerned with robust communication and transmitting secret data [5-6]. Watermarking methods are utilized for providing maintaining the authentication and protecting digital media regarding copyright infringement. [7-8]

Video steganography technology masks the existence of a secret message through hiding this message into the digital video [9]. The merits of utilizing video in information hiding is based on the fact that video is secure with respect to hackers due to relative video complexity compared to image and audio files. So, video may be utilized instead of images as a covert communication medium [10].

Video based steganography may be split into spatial and frequency domain schemes. Spatial domain schemes hide data in cover medium pixels. Least significant bit (LSB) scheme may be considered the most utilized scheme in spatial domain steganography. Transform domain schemes embed data into cover medium transform coefficients by polynomial mathematics [11], Fourier transform, DCT, and DWT. Transform domain schemes may be considered robust when compared to spatial domain schemes [12].

Imperceptibility is considered as the almost effective demand in all data hiding methods and consequently it is necessary to obtain a stego-media in which all alternations are unnoticed and limpid to visual inspection [13-15].

The main paper aim is to propose an efficient DWT-histogram shifting based video data steganography method. The proposed DWT-histogram shifting based video data steganography depends on applying histogram shifting in DWT. The proposed DWT-histogram shifting based video data steganography method is reversible and has the capability of embedding 3 bit per pixel, maximize the embedding capacity and still preserving good visual quality for stego-video. The data to be hidden is not simply inserted on the wavelet coefficients but using histogram shifting for middle and high frequency bands to offer sufficient embedding room.

This paper reset is arranged as follows: Section 2 discusses related works of video steganographic methods. Sections 3 and 4 give basic fundamental knowledge regarding the DWT-histogram shifting based video data steganography by interleaving predictions. Section 5 presents the DWT-histogram shifting based video data steganography. The results are given in Section. 6. Section 7 gives the conclusions.

RELATED WORK

All data hiding applications need hiding/ extracting schemes on transmitter/receiver sides. The hiding process can be secured by secret key employed using authenticated person, so hidden data in encoded video may be retrieved with authenticated person. The important data hiding parameters may include security, invisibility, complexity, reliability, payload, and invisibility.

In 2009, Cetin et al. [16] introduced two video steganographic schemes that use similar and different histograms. Both schemes depend on choosing suitable pixel schemes focused on the cover video perceptibility and capacity parameters. Experimental results prove their efficiency in improving the stego-video temporal and spatial perception levels and offering high data hiding capacity.

In 2013, Dasgupta et al. [17] introduces a video embedding method that utilizes video frames as the cover for hiding data a 3-3-2 LSB as a video hiding scheme. Results demonstrated substantial improvements in PSNR and image fidelity.

In 2015, Ramalingam et al. [18] presented a video hiding that utilizes enhanced hidden Markov model (EHMM) to enhance retrieving hidden data speed. Evaluations are performed to test data retrieval speed using several size cover videos. Tests demonstrated that EHMM gives good outcomes through reducing data embedding time by 3-50%, enhancing extracting speed by 22-77% with 20-91% computational cost, and security enhancement by 4-77%.

Also in 2015, Liu et al. [19] presents a H.264/AVC embedding scheme that divides the hidden data into different sets by a secret key sharing scheme. Results demonstrated that the scheme gives more robustness and high visual quality.

In 2016, Sudeepa et al. [20] proposed a video steganography using LSB and symmetric encryption technique and parallelization. The secret data is hidden random using feedback sit register. Experimental tests demonstrated a remarkable increase regarding its performance and can be utilized or large data volume.

Ramalingam et al. [21] in 2016 reported a scene change detection video steganography using DCT and DWT. Simulation tests demonstrated the superiority of method compare to other methods.

Also in 2016, Liu et al. [22] introduced a video data hiding framework that depends on altering intra prediction modes. The scheme embeds data bits through modifying intra prediction modes in a way which guarantees that the altered prediction mode is almost like the ideal prediction mode. The experiments indicate that the algorithm provides good embedding capacity and stego videos quality.

Finally in 2016, Yao et al. [23] proposes a reversible data embedding in encrypted H.264/AVC. Tests indicate that proposed method has the ability to reconstruct video with good quality.

DISCRETE WAVELET TRANSFORM (DWT)

The DWT may be considered as one of the most widely transformations in digital image processing. The DWT is employed in multi-scale and multi-resolution processing. The DWT realization is shown in Fig. 1. The input signal is applied to two digital filters; known as high pass filter (H0), low pass filter (H1), and followed by factor of (2) sub-sampling [24]. This procedure is named as the Analysis procedure, and the inverse procedure is named the Synthesis process. Two digital filters are employed: high pass filter (F0) as and low pass filter (F1). Both analysis/synthesis procedures are repeated several times as required. The mathematical formulas which represent Analysis/Synthesis procedures are given as:

$$\mathrm{H_i} = \sum_{m=0}^{k-1} \mathrm{x}_{2\mathrm{i}-\mathrm{m}} \cdot s_m(z) \tag{1}$$

$$\mathrm{L_i} = \sum_{m=0}^{k-1} \mathrm{x}_{2\mathrm{i}-\mathrm{m}} \cdot t_m(z) \tag{2}$$

where k represents wavelet filters length.

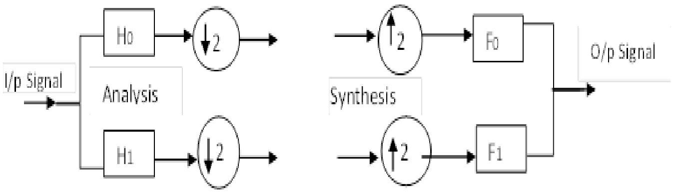


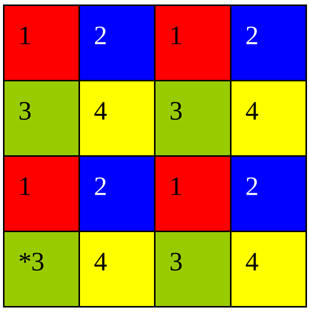
Figure 1: The DWT

INTERLEAVING PREDICTION HISTOGRAM DATA EMBEDDING

Yang et al. [25] introduced an approach that utilizes a column-based interleaving predictions scheme to improve a histogram based data embedding approach [26]. With such method, the odd column pixels are estimated using even column pixels. After that, the even column pixels are estimated using odd column pixels. In [25], a chessboard prediction is studied which may be considered as expansion of column-based interleaving predictions scheme. Because of reduced predicting errors using such approaches, the embedding payload may be raised by increasing peak point's height in histogram.

THE PROPOSED DWT-HISTOGRAM SHIFTING BASED VIDEO DATA STEGANOGRAPHY ALGORITHM

The proposed DWT-histogram shifting based data steganography in video sequences depends on applying an enhanced histogram shifting which extends Yang et al.'s approach [25] in DWT. The proposed DWT-histogram shifting based video data steganography is reversible, capable of embedding 3-bits are and has the capability of maximize the embedding capacity and still preserving good visual quality for stego-video. The data to be hidden is not simply inserted on the wavelet coefficients but using histogram shifting for middle and high frequency bands to offer sufficient embedding room. The pixels order that will be predicted in the proposed DWT-histogram shifting based video data steganography is split into 4 phases as illustrated in Fig. 2. Every cell value defines its processing order.



1	2	1	2
3	4	3	4
1	2	1	2
*3	4	3	4

Figure 2: Pixels numerical orders

$$Mean_{i,j} = \left\lfloor \frac{\sum_{x\in V_{i,j}} T}{\left|V_{i,j}\right|} \right\rfloor \qquad 3$$

where $Pr\_Er_{i,j}$ is predictive error and can be evaluated as:

$$Pr\_Er_{i,j} = T_{i,j} - Mean_{i,j} \qquad 4$$

Assume $Mean_{i,j}$ is adjacent pixels surrounding average and $V_{i,j}$ is a group of surrounding pixels.

Hiding phase

Input: Plain-video PV and secret data D.

Output: The Stego-video $\hat{PV}$, $(peak_{1,1}, zero_{1,1})$, $(peak_{1,2}, zero_{1,2})$, $(peak_{2,1}, zero_{2,1})$, $(peak_{2,2}, zero_{2,2})$, $(peak_{3,1}, zero_{3,1})$, $(peak_{3,2}, zero_{3,2})$, $(peak_{4,1}, zero_{4,1})$ and $(peak_{4,2}, zero_{4,2})$.

1) The PV is split into groups of k frames.
2) Each frame is transformed from RGB to YC_bC_r.
3) Each luminance frame Y is transformed into DWT.
4) For the selected LH, HL and HH bands apply Eqs. 3 and 4 to estimate $Pr\_Er_{i,j}$ for the first phase.
5) Generate the histogram $HIS(h)$ with $h \in [-255, 255]$ using all $Pr\_Er_{i,j}$.
6) Set $(peak_{1,1}, zero_{1,1})$ and $(peak_{1,2}, zero_{1,2})$, as follows:
   a) Choose 2 highest peak points, $(peak_{1,1})$ and $(peak_{1,2})$, from $HIS(h)$, $peak_{1,1} > peak_{1,2}$.
   b) Choose a zero point $Zero_{1,1}$ from $HIS(h)$ with $h \in [peak_{1,1}+1, 255]$, $Zero_{1,1}$, $Zero_{1,1}+1$ and $Zero_{1,1}+2$ is zero; choose a zero point $Zero_{1,2}$ from $HIS(h)$ with $h \in [-255, peak_{1,2}-1]$, $Zero_{1,2}$, $Zero_{1,2}-1$ and is zero.
7) Shift histogram as:

$$Pr\_Er'_{i,j} = \begin{cases} Pr\_Er_{i,j} + 7 & peak_{1,1} + 1 \le Pr\_Er_{i,j} < zero_{1,1} \\ Pr\_Er_{i,j} - 7 & zero_{1,2} < Pr\_Er_{i,j} \le peak_{1,2} - 1 \end{cases} \qquad 5$$

8) Embed the data bits if $Pr\_Er'_{i,j}$ equals $peak_{1,1}$ or $peak_{1,2}$ as follows:
   (a) If the hidden 3-bits is 000, $Pr\_Er'_{i,j}$ is set to $Pr\_Er_{i,j}$.
   (b) If the hidden 3-bits is 001

$$\text{Pr\_Er}'_{i,j} = \begin{cases} \text{Pr\_Er}'_{i,j} + 1 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,1} \\ \text{Pr\_Er}'_{i,j} - 1 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,2} \end{cases} \qquad 6$$

(c) If the hidden 3-bits is 010

$$\text{Pr\_Er}'_{i,j} = \begin{cases} \text{Pr\_Er}'_{i,j} + 2 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,1} \\ \text{Pr\_Er}'_{i,j} - 2 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,2} \end{cases} \qquad 7$$

(d) If the hidden 3-bits is 011

$$\text{Pr\_Er}'_{i,j} = \begin{cases} \text{Pr\_Er}'_{i,j} + 3 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,1} \\ \text{Pr\_Er}'_{i,j} - 3 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,2} \end{cases} \qquad 8$$

(e) If the hidden 3-bits is 100

$$\text{Pr\_Er}'_{i,j} = \begin{cases} \text{Pr\_Er}'_{i,j} + 4 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,1} \\ \text{Pr\_Er}'_{i,j} - 4 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,2} \end{cases} \qquad 9$$

(f) If the hidden 3-bits is 101:

$$\text{Pr\_Er}'_{i,j} = \begin{cases} \text{Pr\_Er}'_{i,j} + 5 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,1} \\ \text{Pr\_Er}'_{i,j} - 5 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,2} \end{cases} \qquad 10$$

(g) If the hidden 3-bits is 100

$$\text{Pr\_Er}'_{i,j} = \begin{cases} \text{Pr\_Er}'_{i,j} + 6 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,1} \\ \text{Pr\_Er}'_{i,j} - 6 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,2} \end{cases} \qquad 11$$

(h) If the hidden 3-bits is 111

$$\text{Pr\_Er}'_{i,j} = \begin{cases} \text{Pr\_Er}'_{i,j} + 7 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,1} \\ \text{Pr\_Er}'_{i,j} - 7 & \text{Pr\_Er}'_{i,j} = \text{peak}_{1,2} \end{cases} \qquad 12$$

9) Convert the $\text{Pr\_Er}'_{i,j}$ as:

$$\hat{T}_{i,j} = \text{Pr\_Er}'_{i,j} + A_{i,j} \qquad 13$$

10) Go to steps 4-9 for the other phases to embed the remaining secret information.

11) Go to Steps 2-10 for the groups of k frames.

12) Merge all the groups of k frames to construct the Stego-video $\hat{M}$.

Extracting phase

Input: Stego video $\hat{PV}$, $(\text{peak}_{1,1}, \text{zero}_{1,1})$, $(\text{peak}_{1,2}, \text{zero}_{1,2})$, $(\text{peak}_{2,1}, \text{zero}_{2,1})$, $(\text{peak}_{2,2}, \text{zero}_{2,2})$, $(\text{peak}_{3,1}, \text{zero}_{3,1})$, $(\text{peak}_{3,2}, \text{zero}_{3,2})$, $(\text{peak}_{4,1}, \text{zero}_{4,1})$ and $(\text{peak}_{4,2}, \text{zero}_{4,2})$.

Output: plainvideo PV, secret data D.

1) The $\hat{\mathrm{PV}}$ is split into groups of k frames.
2) Each frame is converted from the RGB to YC_bC_r.
3) Every luminance frame Y is transformed into DWT.
4) The wavelet coefficients of LH, HL and HH bands are selected.
5) Use Eqs. 3 and 4 to estimate $\mathrm{Pr\_Er}_{i,j}$. Use $(\mathrm{peak}_{4,1}, \mathrm{zero}_{4,1})$, $(\mathrm{peak}_{4,2}, \mathrm{zero}_{4,2})$ and Eq. 14 for extracting three bits data in D_4, and Eq. 15 to retrieve the predictive error values. Let $D_{8.,n}$ is nth bit in D_4.

$$D_{8.,n} = \begin{cases} 000 & \text{if } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,1} \text{ or } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,2} \\ 001 & \text{if } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,1} + 1 \text{ or } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,2} - 1 \\ 010 & \text{if } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,1} + 2 \text{ or } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,2} - 2 \\ 011 & \text{if } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,1} + 3 \text{ or } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,2} - 3 \\ 100 & \text{if } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,1} + 4 \text{ or } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,2} - 4 \\ 101 & \text{if } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,1} + 5 \text{ or } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,2} - 5 \\ 110 & \text{if } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,1} + 6 \text{ or } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,2} - 6 \\ 111 & \text{if } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,1} + 7 \text{ or } \mathrm{Pr\_Er}_{i,j} = \mathrm{peak}_{4,2} - 7 \end{cases} \tag{14}$$

$$\mathrm{Pr\_Er}'_{i,j} = \begin{cases} \mathrm{Pr\_Er}_{i,j} - 7 & \mathrm{peak}_{1,1} + 7 \le \mathrm{Pr\_Er}_{i,j} < \mathrm{zero}_{1,1} \\ \mathrm{Pr\_Er}_{i,j} + 7 & \mathrm{zero}_{1,2} < \mathrm{Pr\_Er}_{i,j} \le \mathrm{peak}_{1,2} - 7 \end{cases} \tag{15}$$

6) Use Eq. 13 to retrieve pixel values of the fourth phase.
7) For the other 3 phases, go to steps 5-6 to retrieve hidden data and its respected pixels.
8) Go to steps 2-7 for the groups of k frames.
9) Merge all the groups of k frames to construct the original video and secret information.

EXPERIMENTAL RESULTS

Data hiding is identified with the imperceptibility and robustness measures. Imperceptibility ensures that hidden data should be statistically invisible. Robustness refers to maximum data amount that may be hidden into the host video without fidelity losing. The perceptual imperceptibility of embedded video is computed with PSNR [27]. To test proposed DWT-histogram shifting based video data steganography, we utilized 3 QCIF (352x288) RGB uncompressed avi video sequences as test cover video of 352x288 resolution and with a frame rate of 30 f/s. Every video has 300 frames. The three standard video are Container, Mother and Daughter and Suzie. The embedded secret data are generated using a predefined data until embedded data with needed length is generated. We employ experimental tests by comparing the proposed DWT-histogram shifting based video data steganography with O.CETIIN et al. method [16]. For demonstrating the effectiveness of DWT-histogram shifting based video data steganography, we implement O.CETIIN et al. scheme [16] and the proposed DWT-histogram shifting based video data steganography using MATLAB software. The obtained experimental tests are shown in Tables 1, 2 and 3. It is clear that the embedding capacity of DWT-histogram shifting based video data embedding is efficient. Also, the PSNR values indicate good video quality with high security level.

Table 1: Comparison of faded pixels number between the proposed DWT-histogram shifting based data steganography and O.CETIIN et al. method [16] for Container.avi cover video

Host video size in bytes	Hidden data size in bytes	Hidden pixels in Host video			
		DWT-histogram shifting based video data steganography		O.CETIIN et al. method [16]	
		Coding	PSNR	coding	PSNR
Container.avi	82	71	49.35	66	46.13
	1600	1566	48.18	1468	45.11
	25,600	25,540	47.56	24,155	44.75
	45,480	43,620	46.65	41,446	43.80
	60,784	58,580	44.85	55,240	42.88

Table 2: Comparison of faded pixels number between the proposed DWT-histogram shifting based data steganography and O.CETIIN et al. method [16] for Mother_Daughter.avi cover video

Host video size in bytes	Hidden data size in bytes	Hidden pixels in Host video			
		DWT-histogram shifting based video data steganography		O.CETIIN et al. method [16]	
		Coding	PSNR	coding	PSNR
Mother_Daughter.avi	82	69	49.35	63	46.2
	1600	1535	48.32	1430	45.4
	25,600	25,320	47.71	24,310	44.86
	45,480	43,456	46.73	41,356	43.88
	60,784	58,440	44.88	55,185	42.92

Table 3: Comparison of faded pixels number between the proposed DWT-histogram shifting based data steganography and O.CETIIN et al. method [16] for Suzie.avi cover video

Host video size in bytes	Hidden data size in bytes	Hidden pixels in Host video			
		DWT-histogram shifting based video data steganography		O.CETIIN et al. method [16]	
		coding	PSNR	coding	PSNR
Suzie.avi	82	75	49.11	68	46.02
	1600	1590	47.75	1480	44.55
	25,600	25,745	46.24	24,635	42.55
	45,480	43,956	44.78	41,657	41.45
	60,784	58,610	43.41	55,880	40.35

CONCLUSIONS

The paper suggested an efficient DWT-histogram shifting based video data steganography based on DWT and histogram shifting. It allows embedding secret data into the second Wavelet decomposition level selected middle and high frequency bands. In the DWT-histogram shifting based video data steganography, the host video is split into frames and histogram shifting of middle and high frequency bands is performed to offer data hiding space. Test results demonstrated that the DWT-histogram shifting based video data steganography is capable of improving significantly the embedding capacity for the stego-video while still keeping high stego-video quality after hiding data.

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