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Data Hiding in the Predictive frames of MPEG Motion Vectors

By

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Abstract:

Compressed video is a target for researchers looking for a secured, robust, reliable, and reversible data hiding techniques. This paper proposes a novel method for hiding data, which is capable of embedding the bits in each candidate MPEG motion vectors. In this method a displacement lookup table is used to embed the secret message (watermarks, signatures, etc.,). The secret message is organized into a stream of three-bit groups then statistically analyzed with histogram. A three-bit distribution at the encoder side is used to build a lookup table of the displacements to the motion vectors with the design objective of minimizing the displacement changes. The associated macro-block prediction error is calculated to decide which motion vectors should be selected for insertion and extraction of the data. These motion vectors are called candidate motion vectors.

The proposed algorithm is tested by embedding the payload (message) at the encoder side in the predictive (P)-frames and successfully extracting it again at the decoder side. The performance is analyzed in terms of peak signal-to-noise ratio (PSNR) and the file size increase of the reconstructed video versus the embedded payload. The results show that the payload of that hidden data is increased compared to other methods using the motion vectors for data hiding. The results for peak signal to noise ratio (PSNR) against the payload give that there is a slight degradation (-2dB) compared to other methods but this degradation is compensated by the decoder.

Keywords:

Data hiding, Watermarking, Motion vectors, Compressed Video, MPEG Data Hiding.

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1. Introduction:

The digital video technology gives the possibilities of using compression in a large number of applications. Some standards were developed for the moving pictures in combined with its audio by the moving picture expert group (MPEG). These standards allow a movie to be compressed and stored on a video compact disk (VCD) as well as another emerging applications like the video on demand (VOD) [1]. This gives the researchers a potential to exploit the various techniques of motion estimation and compensation used for encoding/decoding of the compressed video which has been used in this paper.
The compressed video encoding algorithms uses motion estimation in exploiting the redundancies between the frames with macro-block prediction error. The best estimation algorithms are the ones producing minimum residual error between the current macro-block and the predicted macro-block. The process of finding the best motion is called exhaustive search (ES) which exhausts the resources of the video encoders, and becomes unfeasible. Many video encoders uses fast block searching algorithms instead of full block searching to save precious computational time to other tasks. These fast search algorithms [2,10,11,14,15] include three steps search (TSS), four steps search (FSS), new three steps search (NTSS), simple and efficient search (SES), adaptive rood pattern search (ARPS), and diamond search (DS). These methods do not find the best match for the macro-blocks. This gives a chance to exploit the ones with higher prediction error which could be a candidate to hide the secret data in its motion vector.
Motion Vectors (MV) represents a predicted motion direction in the vertical and horizontal directions denoted by MV (v) and MV (h) respectively. By the prediction process of the fast motion estimation algorithms, there is an error produced which comes from the difference between the actual motion in both directions (vertical and horizontal) and the predicted motion estimated. Measuring the mean squared error (MSE) of the macro-blocks and comparing to an error threshold (T) produces a set (C) called the candidate motion vector . Each member of the set (C) represents a motion vector composed of motion displacement in the vertical and in the horizontal directions. Data Hiding algorithm will exploit that displacement, in which a tiny change to the displacement in the vertical and/or the horizontal components will be done and then extracted at the decoding side while playing the video scene with minimum degradation in the video quality. A good data hiding method should lead to no changes to some of the candidate motion vectors, in which secret bits could be recovered with a suitable mechanism.
The general idea behind data hiding is defined as the science of insertion messages into a host document or cover media. This could give a chance to enlarge the hiding capacity like what has been exploited by Ghanbari et. al., in the medical images (frames) [5]. Also, this could be exploited in the compressed video domain where a three dimensional signal (horizontal, vertical, and time) is used as a host for hiding any binary data acting as a secret messages.
Zhang et. al., [3] proposed a steganographic algorithm in MPEG compressed video stream. In this method each group of pictures (GOP) was used and the control information was used to

guide data extraction that was embedded in intra (I) frame. The secret data were embedded in predictive (P) frames and bidirectional (B) frames and were repeatedly embedded in motion vectors of macro-blocks that have larger moving speed (longer in magnitude than a predefined threshold). Data extraction was also performed in compressed video stream without the requiring original video, since the control information is in the I-frame which should be extracted first then the embedded data in the P and B frames can be extracted based on the extracted control information. Their experimental results show that the proposed algorithm has the characteristics of little degradation to the visual quality, large embedding capacity, and resistance to video processing such as frame adding or frame dropping by redundant embedding.
Fang and Chang [4] used the concept of embedding data in phase angle of the motion vectors by replacing the original motion vector with another local optimal motion vector, and the motion vectors were regularized into a modified bitstream.
In this paper a novel steganographic algorithm for hiding message in a compressed video is introduced. The method is based on hiding every three bits of the message stream into one motion vector in the P frame and reconstructing the message again at the decoder side. The control information is embedded and sent in the I-frames. Furthermore, the embedded data can be extracted directly and independent of the original video sequence.

2. ***The proposed method***

In this algorithm, the secret message cloud be any binary file (text, sound, image, video …etc). The Binary file is statistically analyzed where it is treated as a one dimensional array. Each three bits is converted into their equivalent decimal value. This produces a set of decimal digits composed of eight values [0→7]. Measuring the occurrence of each of the eight values by counting the number of zeros, ones, …, sevens in the message to get a histogram curve as shown in Figure 1.

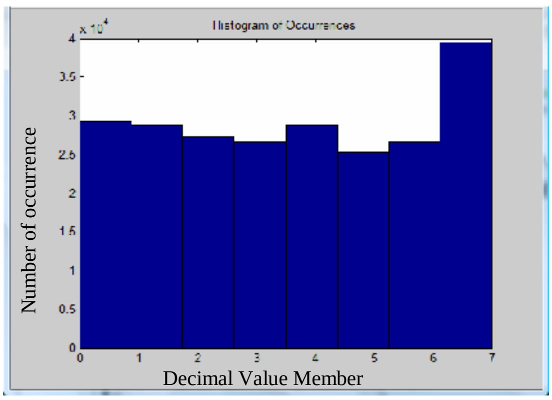


Figure (1): The histogram of the occurrence for each decimal value of the secret message.

The general idea of the lookup table is shown in table 1b to be filled by the result of the histogram analysis.
The means the largest occurrence reflects the displacement in the horizontal direction (dh) by zero and zero displacement in the vertical direction (dv) as well. That's why it was put in the (ii,ii). The second largest occurrence and the third comes in (ii,i),and (ii,iii) cells of the lookup table , that reflects displacements (1) and (-1) in dh respectively as shown in the displacement table 1a. Fourth and fifth largest occurrence was put in the (i,ii), and (iii,ii) which reflects a displacement in the vertical direction to dv by (1) and a horizontal displacement to dh by (-1) and so on.

Table (1): Data encoding sample: (a) The possible 8 neighbors displacements (displacement table). (b) Their corresponding secret data encoding digital values (lookup table).

(a)

V/H	i	ii	iii
i	-1,-1	0,-1	1,-1
ii	-1,0	0,0	1,0
iii	-1,1	0,1	

(b)

V/H	i	ii	Iii
i	5	0	4
ii	2	7	1
iii	6	3	

The proposed embedding method is done as follows:

1- Calculate the mean square error (MSE) of the macro-block error between the reference frame's macro-blocks and target frame's macro-blocks, this produces a two dimensional array whose width and height represents the number of macro-blocks.
2- Obtain the candidate motion vectors based on the macro-block error and a predefined threshold (T) to get the set (C) of candidate motion vectors.
   C= {MVi: MSE(MBi) > = T}, where the cardinality |C|=n, and MB denotes the associated macro-block.
3- Create tampered new motion vectors (MVnew) by adding the corresponding displacements (dv) and (dh) from the lookup table values to both the vertical component (V), and the horizontal component (H) respectively, based on the 3-bits secret message value on the map table (table 1).
   MVnewi(v)= MVi (v)+ dv,
   MVnewi(h)= MVi (h)+ dh, for all 0<=i<=n.

4- The new motion vectors MVnew are used to recalculate the associated macro-block prediction error (MBnew) and both are sent to the decoder. This makes the proposed method blind from the encoder's side.

The proposed extracting method is done as follows:

1- Reconstruct the video for normal viewing by the decoder.
2- Extract the I-frame's sent secret data (macro-block threshold value, lookup table, map table).
3- Calculate the macro-block error between the reference frame's macro-blocks and target frame's macro-blocks, this produces a two dimensional array whose width and height represents the number of macro-blocks.
4- Obtain the candidate motion vectors based on the macro-block error and the predefined threshold T, and get the set C as before.
5- Use the received and calculated motion vectors to get the displacements.
   dv = MVi(v)-MVcalculatedi(v)
   dh = MVi(h)-MVcalculatedi(h),where 0<=i<=n.
6- Exctract the decimal value of the message by reverse lookup from the lookup table, and convert the extracted decimals into binary bits, where eight cases (looktable entries) which generates the message in decimal values and then converted to its equivalent decimal values as follows:
   If ((dv = lookup_table (l,v)) and (dh = lookup_table (l,h))) Then
   Message_decimal(i) = lookup_table (l,decimal_value),
   Messagei_bin(i) = bin(Message_decimal(i)) where 0<=l<=n and 0<=i<=n.

3. Experimental Results

The proposed method is applied to two video sequences: Calendar-train sequence (size 800x704 pixels and 30 frames) and the tree sequence (size 480x704 and 30 frames) which are shown in fig 2. Two different fast block matching algorithms (exhaustive search and three step search) are used for finding the motion vectors. Figures 2 (a) and (b) show two consecutive frames of the calendar train sequence while figure 2 (e) shows the residual error of the compensation process for these frames at the encoder side without embedding any data. Figure 2(f) depicts the residual error of the compensation process for these frames at the decoder side with embedding in the candidate motion vectors with triple bits in each. It also shows that some difference in the visual frames which will not appear at the decoder side after the decoding process. Figures 2(c), (d) show the two consecutive frames of the tree sequence. Figure 2(g) shows the residual error of the compensation process for these frames at the encoder side without embedding any data. Figure 2(h) depicts the residual error of the compensation process for these frames at the decoder side with embedding in the candidate motion vectors with triple bits in each.

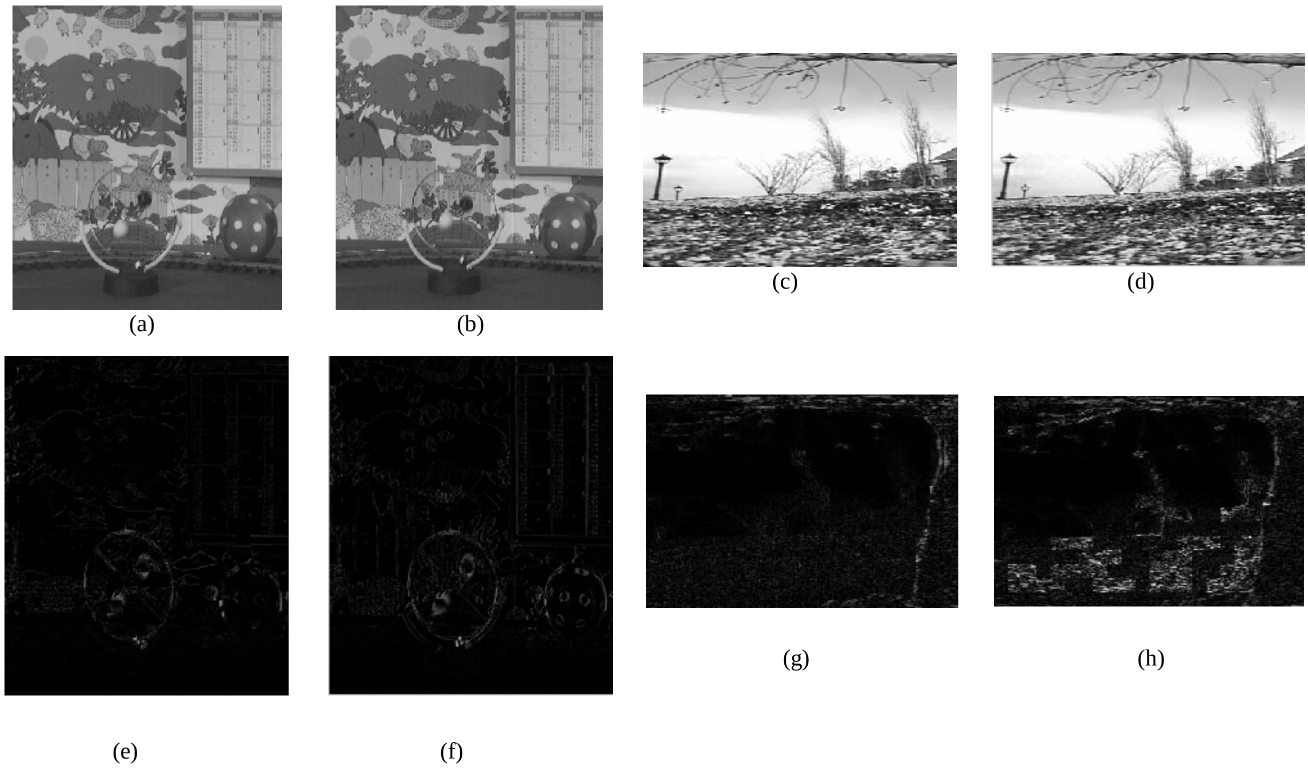


Figure (2): Visual appearance of sample frames.

In figure (3), we compared our results to Zhang et al.[7] method thus we have four experiments, for the two sequences and the two block searching (matching) algorithms (Exhaustive Search (ES), and Three Step Search (TSS)). We measured two factors, In figure 3 we plotted the PSNR and the payload for different thresholds , and the results shows a slight degradation (not visiable) by (1-2) dB as shown in the curves, in return payload was maximized by triple as depicted in the curves.

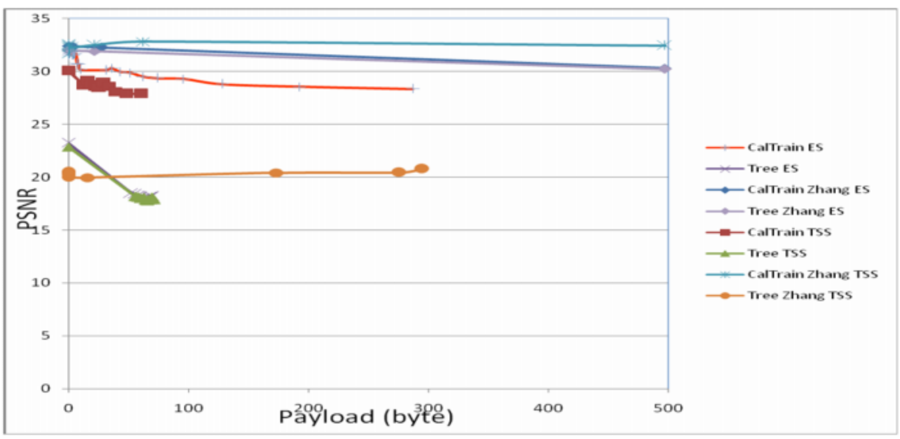


Figure (3): PSNR (db) verses Payload (byte)

Another factor has been studied which is the bit rate distortion (BRD) against the payload, as shown in figure (4). Where the curves shows a small changes in the file size (24%) between the residual error without hiding in motion vectors and after hiding. We compared the BRD against the payload for a JPEG quantization with a quality factor of 75%.The results shows small changes (24%) between our method and Zhang's method.

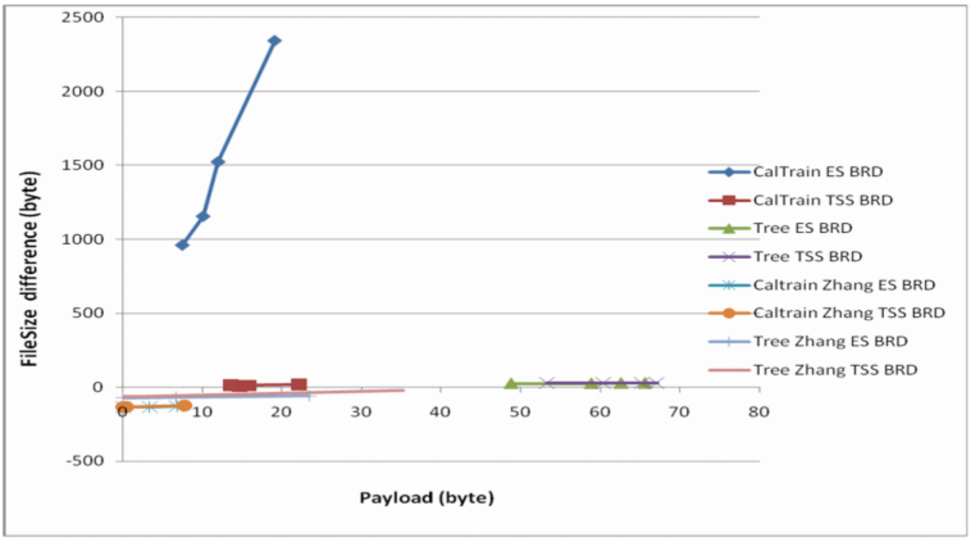
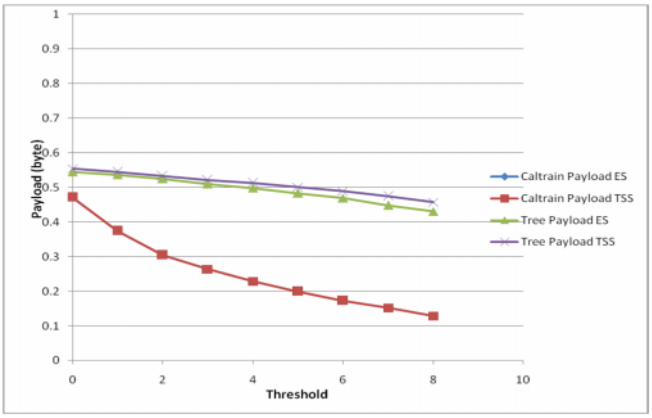


Figure (4): File size difference (byte) verses Payload (byte).

In figure (5) we studied the payload against the threshold, which is the distance in the case of the Zhang's method as shown in figure 5a. And in our method the threshold is the macro–block residual error of the candidate motion vector shown in figure 5b the curves shows that largest payloads comes in the smallest thresholds. On the other hand the payload is decreased with the largest threshold in both methods.

(a)



(b)

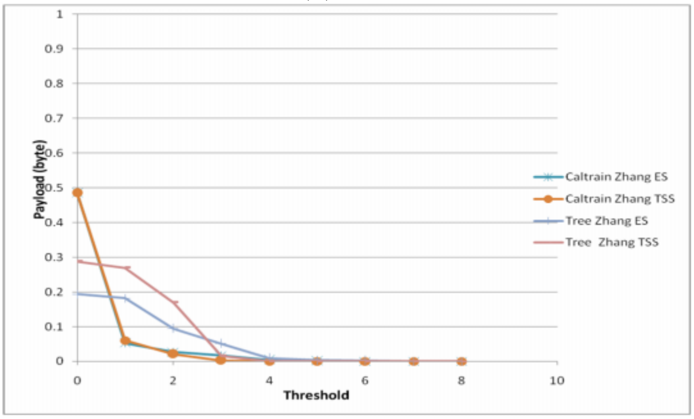


Figure (5) (a) Threshold verses Payload for proposed method. (b) Threshold verses Payload for Zhang's method.

4. Conclusions

The proposed method represents a secured, robust, reliable, and reversible novel data hiding technique. In our paper we proposed a reversible triple bits hiding of data in MPEG motion vectors, in which a displacement lookup table is used to embed the secret messages. The secret message is organized into a stream of three-bit groups after being statistically analyzed with histogram; a three-bit distribution at the encoder side is obtained to build a lookup table of displacements to the motion vectors with the design objective of minimizing the displacement changes. The macro-block error is calculated to decide on the optimum selection of the motion vectors used for insertion and extraction of the data which are called candidate motion vectors. The method shows an implementation of the data hiding method in the predictive (P)-frames and successfully extracted it again at the decoder. We analyzed the performance of our method based on the drop in the peak signal-to-noise ratio (PSNR) and the file size increase of the reconstructed video versus the embedded payload. The proposed method introduced a new triple embedding technique used to hide data in the compressed video domain, exploiting the motion vectors, with minimum visual affection on the quality of the resultant video by the MPEG standards. On the other hand, researches in the field of compressed video data hiding can be contributed by enhancing the payload capacity, and using another point of view for data hiding methodologies by mixing various techniques in the field using the new standard of H.264.

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