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A Secure Process of Hiding Data in Motion Vector of Compressed Video Based on Artifacts

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***Abstract*: There are many researches that have been proposed for hiding the data into digital videos. Most of those schemes uses the attributes of motion vectors like amplitude, phase angle etc. This paper deals with hiding data in compressed video where motion vectors are used to encode and reconstruct both the forward predictive (P-) frame and bidirectional (B-) frames in the compressed video. The subset of motion vectors are chosen based their associated macro block prediction error. Pertinent features will be collected from the motion in between the frames as in the form of the vectors in association with macro blocks and depending on the motion message is going to be hidden. To achieve the robustness a adaptive threshold is searched and low predictive error level is retained. Secret message bits are hidden in Least significant bit of both components of candidate motion vector. The evaluation will be based on two criteria: minimum distortion to reconstructed video and minimum overhead on compressed video size.**

***Index Terms*: Data hiding, Minimum Picture Expert Group (MPEG), Motion vectors, Prediction error, Steganography.**

I. INTRODUCTION

The way in which digital data can be distribution have been revolutionized by the internet and the world wide web. With the advancement in the communication, the access of images, videos and other documents has become much easier, which led to the development data hiding. Data hiding is the process secretly embedding the information inside a data source without changing its perceptual quality, with a minimum amount of perceivable degradation, that is, the embedded data is invisible or inaudible to a observer. Data hiding consists of two sets of data, the cover medium and the embedding data or the message. The medium can be text, audio, picture or video depending on the size of the message and the capacity of the cover medium.

The internal dynamics of video compression, specifically the motion estimation stage, are processed internally during the video encoding/decoding which makes it hard to be detected by image steganalysis methods and is lossless coded, thus it is not prone to quantization distortions. Spread spectrum and other methods like this were used, where basically the message is distributed over a wide range of frequencies of the host data. Transform domain is preferred for hiding data, for the same robustness as for the spatial domain; the result is more pleasant to the Human Visual System (HVS). For this purpose the DFT (Discrete Fourier Transform), the DCT (Discrete Cosine Transform), and the DWT (Discrete Wavelet Transform) domains were usually employed [8-10].

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Recent video data hiding techniques are focused on the characteristics generated by video compressing standards. Motion vector based schemes have been proposed for MPEG algorithms[3]. Motion vectors are calculated by the video encoder in order to remove the temporal redundancies between frames. In these methods the original motion vector is replaced by another locally optimal motion vector to embed data.

First the video is divided into blocks and next the message is came in to existence therefore the message is encoded in the least significant part of the block and is given as 16*16, 16*8, 8*8, 8*16 respectively. Therefore here the data hiding is not a major task and also the data decoding is also not a major task but the main thing we are supposed to concentrate is on the clarity level or the mean square error (MSE) that is noise and also on the loss of the data [2-4].

Quantization errors are also important factor. Therefore quantization is nothing but the setting the predefined values or may also be defined as the rounding off making it to the nearest value respectively. Therefore there is no problem at the time of the quantization at the encoding stage but the main challenge is at the receiver end at the time of the decoding of the data that is nothing but the dequantization of the data at the decoding stage so these comes under the quantization error. Due to this there is a lack of pixels and may lead to clarity loss etc. Here, the data bits of the message are hidden in some of the motion vectors whose magnitude are above a predefined threshold, and are called candidate motion vectors (CMVs). A single bit is hidden in the least significant bit of the larger component of each CMV.

II. BASIC CONCEPT AND NUOTATION

At the encoder, the Intrapredicted (I)-frame is encoded using regular image compression techniques similar to JPEG but with different quantization table and step; hence the decoder can reconstruct it independently. The I-frame is used as a reference frame for encoding a group of forward motion-compensated prediction (P)- or bidirectionally predicted (B)-frames. In the commonly used Motion Picture Expert Group , the video is ordered into groups of pictures (GOPs) whose frames can be encoded in the sequence: [I,B,B,P,B,B,P,B,B]. The temporal redundancy between frames is exploited using block-based motion estimation that is applied on macroblocks $ß_{ij}$ of size $b \times b$ in P or B and searched in and searched in target frame(s). Generally, the motion field in video compression is assumed to be translational with horizontal component d^x and vertical component d^y and denoted in vector form by **d(x)** for the spatial variables X=(x,y) in the underlying image.

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The search window is constrained by assigning limited -bits for ; in other words, both d^x and d^y ε$[-2^{n-1}-1,2^{n-1}-1]$, which corresponds to$[-2^{n-2}-1/2,2^{n-2}-1/2]$, pixels if the motion vectors are computed with half-pixel accuracy. An exhaustive search in the window of size $b+2^n \times b+2^n$ can be done to find the optimal motion vector satisfying the search criterion which needs many computations, or suboptimal motion vectors can be obtained using expeditious methods such as three steps search, etc.; this is based on the video encoding device processing power, the required compression ratio, and the reconstruction quality. Since **d** does not represent the true motion in the video then the compensated frame using (**x**+d(**x**)) must be associated with a prediction error $E(x)=(P-\tilde{\hat{P}})(\mathbf{x})$ in order to be able to reconstruct $P=\tilde{\hat{P}}+E$ with minimum distortion at the decoder in case of a P-frame.

Similar operation is done for the B-frame but with the average of both the forward compensation from a previous reference frame and backward compensation from a next reference frame. *E* is of the size of an image and is thus lossy compressed using JPEG compression reducing its data size. The lossy compression quantization stage is a nonlinear process and thus for every motion estimation method, the pair (**d**,E)will be different and the data size *D* of the compressed error $\tilde{E}$ will be different. The motion vectors are lossless coded and thus become an attractive place to hide a message that can be blindly extracted by a special decoder.

The decoder receives the pair (**d**, $\tilde{E}$), applies motion compensation to form $\tilde{\hat{P}}$or $\tilde{\hat{B}}$, and decompresses $\tilde{E}$ to obtain a reconstructed E_r. Since E and E_r are different by the effect of the quantization, then the decoder in unable to reconstruct *P* identically but it alternatively reconstructs $P_r=\tilde{\hat{P}}+E_r$. The reconstruction quality is usually measured by the mean squared error P-P_r, represented as peak signal-to-noise ratio (PSNR), and we denote it by $\mathfrak{R}$.

Problem Identification

Data hiding in motion vectors at the encoder replaces the regular pair **(d^h, $\tilde{E}$)** due to tampering the motion vectors, to become (**d^h**, **$\tilde{E}^h$)** where the superscript denotes hiding. Data hiding in motion vectors of compressed video is defined in the context of super-channel [7]; the secret message *m* is hidden in the host video signal ***x=(d,E)*** to produce the composite signal s=(**d^h, E^h).** The composite signal is subject to video lossy compression to become y=(**d^h**, **$\tilde{E}^h$**). The message should survive the video lossy compression and can be identically extracted from y. This robustness constrain should have low distortion effect on the reconstructed video as well as low effect on the data size (bit rate).Given that *m* can be identically extracted, in this paper, two metrics used to evaluate data-hiding algorithms in compressed video which are:

1. Increase in data size, ΔD
2. Drop in the reconstruction quality

This reconstruction is with quality loss than that without data hiding,Δ $\mathfrak{R}$ and expressed as the PSNR difference which is as well that of the quantity of the relative error for P- and B-frame.

The objective is to provide a good data-hiding algorithm that should maintain ΔD and Δ$\mathfrak{R}$ as close to zero as possible for a given data payload. The payload should be robust to the video compression, specifically the quantization step applied to the prediction error E.

The selection of the CMV is the key difference between different methods. For instance [9] and [10] choose the CMV based on their magnitude d'={d:||d|| < threshold}.On the other hand [4] and [6] rely on the magnitude and the phase between consecutive motion vectors. Their idea is that motion vectors with large magnitude are less likely to represent the real underlying motion accurately and thus their associated macro block prediction error E is expected to be large. Tampering these CMVs will not affect the reconstruction quality that much.

1) not all motion vectors with large magnitude are associated with macro blocks of high prediction error,

2) there are motion vectors whose magnitude is small but their associated macro block prediction error is high.

These observations stimulated our proposal to rely directly on the associated macro block prediction error, such that we choose our CMV associated with macro blocks of high prediction error. If we tamper with these CMVs, then we will not have poor effect on the video reconstruction quality. Since PSNR is a reciprocal of the mean squared error (mse), then our selection criteria in this paper can be thought of as

$$d'=\{d:10\log_{10}(b^2/\sum ß_{i,j}\, E(x))\leq\tau\}$$

In this direction, we choose the CMV based on the pair (**d**,E) and not **d** alone However, this incurs the difficulty that E is lossy compressed and what we have at the decoder after decompression is actually E_r.

III. PROPOSED METHOD

In the proposed method pertinent features will be collected from the motion in between the frames as in the form of the vectors in association with macro blocks and depending on the motion message is going to be hidden.

The proposed algorithm of data hiding is applied at the encoder side, uses the regular pair (d,E) produced, tampers d to become d^h and thus replaces them by the pair (d^h,E^h) for each P and B frame in the GOP. The secret message is organized as a bit stream m(k) , 0 < k < K message length. A subset of d is selected to be the CMV. The CMV is obtained if their associated macro block prediction error measured in PSNR is below an initial threshold value. The least significant bit (LSB) of both components, are replaced by bits of the message. After data embedding, we will validate the used value by other algorithm.

The algorithm will test the robustness of the hidden message to the quantization effect of the JPEG compression. For the prediction error E^h, it will perform the compression by the encoder followed by the decompression performed by the decoder. If the reconstructed prediction error E_r^h maintains the same criterion given below

$$(10\mathrm{Log}_{10}(b^2/\sum ß_{i,j}\, E^h{}_r(x)) < \tau_{key})$$

Then d' can be identified by the data extractor for the given value of τ_{key}. If any macro block associated with fails to maintain the criterion, then will not be identified by the data extractor and the message will not be extracted correctly.

Hence, the method is proposed to use an adaptive threshold by iteratively decrementing τ_{max} by 1 dB, for this frame until either the criterion is satisfied for all macro blocks or the stopping value τ_{min} is reached for which no data is embedded in the frame.

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Since the threshold used for each frame is different, eight values for that GOP in I frame can be hidden using robust image data-hiding technique or sending them on a separate channel based on the application. This decreasing of threshold will decrease the payload and vice versa, thus the maximum feasible adaptive threshold for each frame is searched.

The decoder receives the pair and it can decode d^h without loss and decompresses obtained compressed error to obtain a lossy reconstructed version E_r^h. During normal operation for viewing the video, the decoder is able to reconstruct P^h or B^h by suitable compensation from reference frames.

This work is a new kind of motion estimation. Algorithm will have two effects on the new compressed video: change in data size and reconstruction quality. The data extractor operates to extract the hidden message as a special decoder. After data extraction from the consecutive GOPs the hidden message is reconstructed back by concatenation of the extracted bitstream.

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Proposed Algorithm

STEP I. **DATA HIDING**

1. Enter message bitstream, GOP
2. For each P and B frame do
3. initialize $\tau_{key}=\tau_{max}$
4. repeat
5. set $d^h=d$
6. Obtain the CMV
7. while (k≤K)& for all (i,j)ε $d_{i,j}(x)$ do
8. replace LSB $d_{i,j}^{rx}$ =m(k)
   LSB $d_{i,j}^{ry}$=m(k+1)
9. k=k+2
10. if B frame then
11. replace for backward compensation motion vectors LSB
    LSB($d_{i,j}^{rx}$)=m(k)
    LSB($d_{i,j}^{ry}$)=m(k+1)
12. k=k+2
13. end
14. $d_{i,j}^{h}=d'_{i,j}$
15 end
16 . Compute associated prediction error $E^h(x)$ by suitable compensation using $(x+d^h(x))$
17. [keyfound, τ_{key}]← validate τ
18. until keyfound or $\tau_{key}=\tau_{min}$
19. if not keyfound then
20. $\tau_{key}=-1$
21. end
22. hide τ_{key} in I-frame or on a separate channel
23. end

STEP II.**Test the Robustness of the hidden message**

STEP III. **DATA Extraction**

1. Inputs are Hidden GOP
2. Extract threshold for all frames in GOP from I-frame or use them from other channel
3. For each P and B frame in GOP do
4. Decompress Prediction Error
5. Identify CMV
6. For each (i,j) ε $d_{i,j}(x)$, do
7. extract 2 message bits m(k)=LSB($d_{i,j}^{rx}$)
   m(k+1)=LSB($d_{i,j}^{ry}$)
   k=k+2
8. If B-frame then
9. Extract from backward compensation motion vector 2 message bits
   m(k)=LSB($d_{i,j}^{rx}$)
   m(k+1)=LSB($d_{i,j}^{ry}$)
10. k=k+2
11. end
12. end
13. end

IV. CONCLUSION

A new data-hiding method in the motion vectors of MPEG compressed video is proposed. Unlike most data-hiding methods in the motion vectors that rely their selection on attributes of the motion vectors, this paper chooses a different approach that selects those motion vectors whose associated macroblocks prediction error is high and low PSNR to be the candidates for hiding a bit in each of their horizontal and vertical components. Therefore, providing the protection for the message from the third party users or simply the hackers.

Here the main thing is that the pertinent features are collected from the motion in between the frames as in the form of the vectors in association with macro blocks and depending on the motion message is going to be hidden. The macro blocks are in such a way that is one different procedure for the selection of the macro blocks based on thresholding method where the CMV is corresponded.

Search for the suitable value of the threshold to be used is made for choosing the macroblocks corresponding to the CMV is done such that the candidates will be identically identified by the decoder even after these macroblocks have been lossy compressed. The embedding and extraction algorithms will be implemented and integrated to the MPEG encoder/decoder and the results will be evaluated based on two metrics: quality distortion to the reconstructed video and data size increase of the compressed video. The proposed method will try to have lower distortion to the quality of the video and lower data size increase. Comparisons with existing methods which uses motion vector attributes will also be done. The proposed algorithm may be used for MPEG-2 encoder/decoder. The size of embedded payload may be increased while maintaining the robustness and low distortion.

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