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DCT based Reversible Information Hiding Scheme For Video using Quantized Blocks

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Abstract—The reversible data hiding is used for lossless and reversible streganography scheme for hiding secret data in quantized descret cosine transformation (DCT) blocks. The requirement of reversibility may lead to more modifications to the cover content which result in the tradeoff between the visual quality and hiding capacity. In this paper we propose a reversible information hiding scheme for video, to embeds the information into non-zero AC coefficients of quantized DCT blocks. The experimental results show that the proposed scheme improves both the visual quality and hiding capacity.

Index Terms—*Reversible, DCT, capacity, visual quality, non-zero AC coefficients.*

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I. INTRODUCTION

Now a days, the reversible data embedding is emerging due to its vast applications in military communication, re- mote sensing, medical imaging, fine arts, multimedia archive management etc. which require the restoration of the original content such as image, audio, video etc. after the extraction of the embedded data. The practice of reversible embedding is carried out in both the compressed and uncompressed domains of the cover content. The most widely used compression standards such as JPEG, MPEG, JVT, H.264, etc. are very popular in compressed domain embedding. In the recent, the compressed domain data embedding has become an active area of research for efficient storage and transmission [1], [2], [3]. The DCT (Discrete Cosine Transformation) is used most widely for transforming the multimedia data to the frequency domain in most of the compression standards such as JPEG, MPEG, JVT, ITU's H.261 and H.263, etc. Embedding the data into the quantized DCT coefficients is the most common practice [4], [5] in the state of art.

In general, the process of achieving reversibility causes more modifications to the cover content which in turn results in visual degradation of the content. This warrants the trade off between the visual quality and embedding capacity [1]. Most of the reversible schemes in literature fail to strike the trade off [6], [7], [8]. Therefore, there is a need to explore the ways of making this trade off in designing a reversible scheme. To address this issue, we propose a reversible data embed- ding scheme for MPEG-4 video which embeds the data into quantized DCT coefficients. observing most of the standard QCIF formatted videos, we identified that most ofthe AC coefficients in a quantized DCT block are centered around zero [8]. By this observation we designed a reversible data embedding scheme which makes use of the non-zero AC coefficients of the quantized DCT blocks. Our design aims at minimizing the alterations to the cover while achieving the reversibility.

The proposed scheme is compared with C- C. Chen scheme. The proposed scheme improves both the visual quality and embedding capacity.

The paper is organized as follows. Section II briefly reviews the MPEG-4 compression and our proposed scheme for em- bedding the data during the process of MPEG-4 compression will be detailed. Results and discussion is given in Section III. We conclude the paper in Section IV.

II. PROPOSED SCHEME

We embed the data into the MPEG-4 video during the process of compressing the raw YUV video into MPEG-4 format. Broadly, the embedding framework in MPEG-4 include the formation of intra coded frames and inter coded frames followed by encoding. Specifically, it include the components like DCT, quantization, embedding, prediction, encoding as in Figure 1. The MPEG-4 compression involves the formation of sequence of three kinds of frames: I -, P -, B- $frame$. The I -f $rames$ are called *reference frames* and P -, B- $frames$ are called *predicted frames*. The I -$frames$ are coded using *Intraframe* technique, i.e, they can be reconstructed without having the reference to any other frames. The P - $frames$ are coded using *Interframe* technique called *forward prediction*. They are forward predicted from the recent I- $frame$ or P -$frame$. The B-$frames$ are also coded using *Interframe* technique but they are both *forward predicted* from the recent and *backward predicted* from the future I -$frame$ or P -$frame$, i.e, two other frames are necessary to reconstruct the B-f $rames$. Hence, in the MPEG-4 compression the I - $frames$ are the key frames without which the reconstruction of the compressed video is not possible. Multiple feedbacks can be used by the encoder in predictive coding to improve the performance of coding. In this paper, we choose the luminance component (Y) of the every I *-frame* for embedding the data.We take the 8 × 8 block of a luminance component (Y) of an I*-frame*,

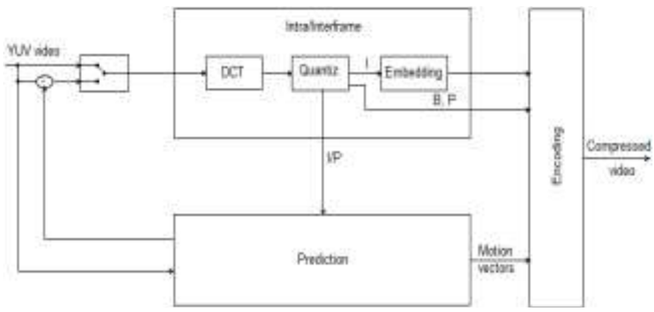

Figure 1: The framework of embedding in MPEG-4

get the quantized DCT coefficients and embed the data into it. Note that we present only the steps of interest in MPEG-4 compression in Figure 1.

a. Models and Notations

The raw YUV video consist of sequence of frame F = $\{\bar{f}1, \bar{f}2, ..., \bar{f}n\}$ be the sequence of original frames of raw YUV video ,where 'n'is the total number of frames .each frame f_i€ F consists of one luminance ,two chroma components. Let $\bar{f}i$ = $\{$Y, Cb, Cr$\}$ where Y is the luminance component and Cb, Cr are the two chroma components of f_i. .all these components can be compressed using MPEG-4 encoder. While the compression process is being carried out, the MPEG-4 encoder expresses the frames in F as the sequence of I-,P-,B- frames. Then *F-=I ᴗPᴗB*, where I is the set of I-frames called reference frames and P,B are the sets of P-,B- frames, which are the predicted frames .Though, all the frames in F- can be used for embedding the data ,we use only I-frames for embedding .Let Let $I = \{I1, I2, ..., Im\}$ where m<n. as we concern with I, let $Ii=\{Y^i,C^i_b,C_r^i\}$,where Y^i is the luminance component of Ii, $C^i_b$and C_r^i are the two chroma components of Ii. we consider Y^i embedding the data. Here each Y^i, of size $n_1 xn_2$,is partitioned into 8x8 blocks of intensity values. we assume that both n_1,n_2 are the multiples of 8. Let $Y^i=\{B_1^i{}^{,}B^i_2 ....,B^i_l\}$,Where B^i_j is the j^{th} 8X8 block of Y^i and l=(n_1xn_2)/64.Here $m^\wedge$=mxl gives the total number of blocks in the setI . These 8x8 non-overlapping blocks are transformed into 2-dimensional DCT using (1).

$$F_{u,v} = \frac{\alpha(u)\alpha(v)}{4}\sum_{x=0}^{7}\sum_{y=0}^{7}B_j^i(x,y)\hat{g}(x,y,u,v) \qquad (1)$$

where

$$\hat{g}(x,y,u,v) = \cos\left(\frac{(2x+1)u\pi}{16}\right)\cos\left(\frac{(2y+1)v\pi}{16}\right)$$

$$\alpha(e) = \begin{cases} \frac{1}{\sqrt{2}} & \text{if } e = 0, \\ 1 & \text{if } e \neq 0. \end{cases}$$

Here,0≤ u,v≤7,and $B^i_j(x,y)$ represent the intensity value (pixel value) of block B^i_j at the coordinate (x,y)in the special domain and $F_{u,v}$ represent the coefficient at the coordinate (u,v) in the frequency domain .the inverse DCT(IDCT) is obtained by (2) as follows ,where α(e) are the same as in (1),and 0≤x,y≤7.

$$B_j^i(x,y) = \sum_{u=0}^{7}\sum_{v=0}^{7}\frac{\alpha(u)\alpha(v)}{4}F_{u,v}\hat{g}(x,y,u,v) \qquad (2)$$

Let $B^{\wedge i}=\{B^\wedge 1, B^\wedge 2, ... B^\wedge_l\}$ be the set of 8x8 blocks of DCT coefficients of Y^i,and Q be a 8X8 block of the quantization table used in intraframe coding .Let $C^i= \{C1,C2,C3....C_l\}$ be the set of 8x8 blocks of quantized DCT coefficients and $C^{i\wedge}=\{C'1,C2',......C,_l\}$be the set of embedded blocks of Y^i.Let D_i(1≤i≤9) be the set of quantized DCT coefficients from high frequency to low frequency of a 8x8 block as show in figure 2[6]. Let $(d_{i,1},d_{i,2},....d_{i,k(i)})$ be the sequence of quantized DCT coefficients in the set D_i,where k(i) is given in table (1).

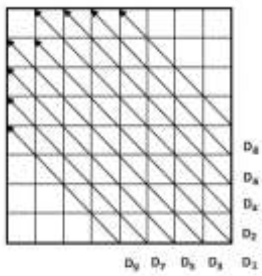

Figure 2: Chosen sets for embedding

i	1	2	3	4	5	6	7	8	9
K(k)	7	7	7	6	6	5	5	4	4

Table 1: The size of the chosen sets for embedding

b. Data Embedding Procedure

We embed the data intonon zero AC coefficient of quantized DCT blocks . The sets D_k ($1 \le k \le 9$) are considered for embedding as shown in Figure 2[7]. I x = $d_{k,p}$ here $1 \le p \le K(k)$, use the following f, S, g functions where f is used to hide the bit, S is used to extract the data bit and g is used to restore the modified coefficients.

$$x' = f(x) = \begin{cases} x+1 & \text{if } x \geq 2 \\ x-1 & \text{if } x \leq -2 \\ x & \text{if } x = \pm 1 \text{ and } s = 1, \\ x+1 & \text{if } x = 1 \text{ and } s = 0, \\ x-1 & \text{if } x = -1 \text{ and } s = 0, \\ 0 & \text{if } x = 0. \end{cases} \quad (3)$$

where t is data bit in I to be embedded .

$$S(x) = \begin{cases} 1 & \text{if } x = \pm 1 \\ 0 & \text{if } x = \pm 2 \\ \perp & \text{otherwise} \end{cases} \quad (4)$$

$$g(x) = \begin{cases} x+1 & \text{if } x \geq 2 \\ x-1 & \text{if } x \leq -2 \\ x & \text{if } x = \pm 1 \\ 0 & \text{if } x = 0. \end{cases} \quad (5)$$

These functions satisfy the following conditions:

1) $|x - x'| \leq 1$.
2) For all x; $f(x) = x' \Rightarrow g(x') = x$.
3) *For all x; the function S(x) outputs abit from the set { 0, 1} or the symbol* $\perp$, which indicate that no bit is embedded in *x*.

The algoritham for above proposed method is presented as following During the compression, F is given as input to the encoder . as it is stated as earlier the encoder expresses the frames of *F* as the sequence of *I* -, *P* -, *B-frames*. We consider the set of *I-frames* for embedding the data bits. We present our proposed data embedding scheme in Algorithm 1.

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Algorithm 1: Data embedding scheme
Input : I={I_1,I_2,…………I_m} be the set of I-frames
and Ï be the data to be embedded .
Output: the set of I-frames with embedded data
forall the I_i € I do
extract the Y^i from I_i
partition $Y^i \rightarrow \{B_1^i, B_2^i, \ldots, B_l^i\}$
for each B_j^i€ Y^i ,where $1 \leq j \leq l$ do
find the DCT coefficients in B^i_j :$\dot{B}_j^i$ = DCT(B_j^i);
quantized DCT coefficients in $\dot{B}_j^i$ in as
Below :
For $i_1 \leftarrow$ 1 to 8 do
for $i_2 \leftarrow$ 1 to 8 do
$C_j(i_1,i_2) = \dot{B}_j^i(i_1,i_2)/Q(i_1,i_2)$;
end
end
consider D_k($1 \leq k \leq 9$) sets of C_j as shown in figure2;
if $x = d_{k,p}$ where $1 \leq p \leq K(k)$,embed the bit S from I using the function f in equation (3)
Let the resultant block be C_j';
end
combine all the C'_j;
$C^{\wedge i} \leftarrow \{C_1, C_2, \ldots, C_l\}$;
restore the $C^{\wedge i}$ back to I_i={C^i,C_b^i,C_r^i}
end

C. Data Extraction Procedure

The data extraction is an inverse process of data embedding. We extract the data bits using the function *S* and restore the modified coefficients using the function *g*. The data extraction and restoration is presented in Algorithm 2. We can prove that the proposed scheme is reversible by showing the function *f* is invertible to the function g.

Algorithm 2: Data extraction scheme:
Input: I, the set of I-frames with embedded data
Output: the set of restored I-Frames, and the extracted Data: Ï'
forall the I_i€ I do
Extract the $C^{i\wedge}$ from I_i;
Partition $C^{i\wedge} \rightarrow \{C'_1, C'_2, \ldots C'_l\}$
foreach C_j'€ $C^{\wedge I}$ do
consider D_K ($1 \leq k \leq 9$) sets of C'_j as shown in figure 2;
begin
if $x = d_{k,p}$ where $1 \leq p \leq K(k)$,extract the data bits using the fuction S in the equation (4)
restore the modified coefficients using the function g in the equation (5)
end
Let the resultant block be E_j';
De-quantize the elements of E_j' as follows :
for $i_1 \leftarrow$ 1to 8 do
for $i_2 \leftarrow$ 1to 8 do
$R_j(i_1,i_2) = E_j'(i_1,i_2) \times Q(i_1,i_2)$;
end
end
$R_j'(i_1,i_2)$= IDCT(R_j');
end
combine all the R_j' blocks to get the $R^{i\wedge}$
$R_j^{\wedge} \leftarrow \{R'_1, R'_2, \ldots R_l'\}$;
Restore the $R^{i\wedge}$ back to I_i={$R^{i\wedge}$,C_b^i,C_r^i}
end

III. Results and Discussion

We use various QCIF formatted videos in our experiment, including MissAm, Akiyo, Foreman, SalesMan, etc. Some of the test videos are shown in Figure 4. The frame size of all these test videos is 176 × 144 pixels. We compress these test videos by the standard MPEG-4 encoder. The widely used measurement for evaluating the visual quality of a stego-video (watermarked video) is PSNR (Peak Signal to Noise Ratio). The PSNR for each YUV channel of a frame is given by the following equation:

$$\text{PSNR} = 10 \log_{10} \frac{255^2}{MSE}, (dB) \quad (6)$$

where

$$MSE = \frac{1}{MN} \sum_{x=1}^{M} \sum_{y=1}^{N} (f_{x,y} - f'_{x,y})^2 \text{ and } f_{x,y}, f'_{x,y}$$

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87 – 91

Are the pixel values at the coordinate (x, y) of original and distorted (embedded) video YUV channels respectively, each of size $M \times N$.
Further, we use the HVS based visual quality mesure PSNR-HVS-M [9] denoted by $PSNRM$, which takes into account the sensitivity of human eyes to distortions in high, low spatial frequencies and the masking effects given as follows.

$$\text{PSNR-HVS-M} = 10\log_{10}\frac{255^2}{MSE^{HVS-M}}, (dB) \qquad (7)$$

where $MSE^{HVS\text{-}M}$ is computed between the original and embedded (distorted) luminance component Y^i.
Another measurement used for evaluating the performance of a data embedding scheme is *embedding capacity*. We define the embedding capacity as the number of bits that can be embedded into a single Y^i. The results are shown in Table II. From the Table II, it is evident that using the proposed scheme the visual quality is improved in terms of both the PSNR and $PSNRM$ compared to C-C. Chen scheme. Further the embedding capacity is also higher for most of the test video sequences. This is because our design minimizes the alterations to the coefficients and utilize coefficient /1/ for embedding the data which are more in the number. The embedded I-frames of various test video sequences are shown in Figure 4.

IV. CONCLUSION

When the data is hidden in the DCT domain. The modifications to the cover content need to be minimal for achieving reversibility. This results into a better trade off between the visual quality and hiding capacity. Int the proposed scheme improves both the visual quality and the hiding capacity.

Table II: Comparison of proposed scheme for various test videos

	C-C Chen et al. scheme [6]			Proposed Scheme		
Video Sequence	Capacity	PSNR	$PSNRM$	Capacity	PSNR	$PSNRM$
MissAm	779	34.3489	32.3898	767	37.0801	34.9831
Akiyo	1109	31.5554	32.1918	1460	33.5383	32.9557
CarPhone	1571	30.1427	31.6978	1744	32.2726	32.6588
SalesMan	1907	29.0330	31.3962	2545	31.4584	31.1866

(a) MissAm (b) Akiyo (c) Foreman (d) SalesMan
Figure 4: The four original I frames of various test videos

(a) MissAm (b) Akiyo (c) Foreman (d) SalesMan
Figure 6: The embedded I frames of test videos

ISSN: 2321-8169
87 – 91

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