Information Hiding Algorithm for H.264 Based on the predition difference of Intra_4×4

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Abstract—**A scheme of information hiding for H.264 based on the prediction difference of intra_4×4 is proposed in this paper. According to this difference, the proposed algorithm first divided the intra_4×4 prediction modes (I4-modes) into two groups to form the rule of mapping between these modes and the bits to be hidden, and then modified the I4-modes by the rule of mapping to implement the hiding of information. By introducing the rate-distortion cost during the process of modulating, the proposed scheme achieved a better balance of rate-distortion, meanwhile, it had a smaller influence on the quality of video and the bit-rate of video. This scheme could detect the secret information rapidly, which meets the requirement of the real-time processing of video. Experimental results also demonstrate that it is a extremely effective scheme.** *(Abstract)*

Keywords-information hiding; H.264/AVC; intra prediction; Logistic mapping(keywords)

I. INTRODUCTION

Information hiding, a technology of confidential communication, has become a hotspot in the field of multimedia information security [1-2]. It embeds important information into other media (carrier) without changing the external features and value of the carrier, so that can realize the transmission of important secret information. Video, as an important information carrier, is often considered to be an important object for information hiding. The existing schemes of information hiding based on MPEG1 and MPEG2 embedded hidden information mainly through adjusting the I-frame's DCT coefficients[3-4]. However, the technology of intra prediction in the I-frame is used in H.264/AVC, which makes extremely small the residual coefficients after the transformation of DCT and quantization. Consequently, these traditional methods are difficult to be directly applied to H.264 standard. The existing algorithms of information hiding based on the H.264/AVC are implemented mainly by restricting the coding mode of macroblock.

The least significant bit of IPCM macroblock is selected to embed information in [5] by Kapotas. The method had a good imperceptibility, but in fact macroblocks with the mode of IPCM are very scarce. The capacity of hidden information is relatively small. The hidden information is embedded in [6] by limiting the encoding modes of macroblock , namely 16×16, 16×8, 8×16 and 8×8. The algorithm does not take into account rate-distortion cost of different encoding modes, and has a great impact on the quality of video and bit-rate of video. The Algorithm proposed in [7] is similar to [6]. It embeds information by limiting the macroblock type in I and P frame, which increased the embedding capacity. However, this approach still does not take into account rate-distortion cost of different encoding modes. Cao[8] proposed a hiding scheme by modulating the coding mode of some 4 × 4 luminance blocks in I frame according to the mapping rules between the prediction modes and the bits to be hidden solely based on emerged probability of prediction modes. The contents of the different sequences vary widely. Consequently, such statistical results are not clearly universal. In this paper, we propose an information hiding method based on predicting difference by analyzing the intra_4 × 4 prediction modes (I4-modes). Information hiding is implemented by modulating the I4-modes based on the mapping rule established according to the prediction difference. The locations of hiding were chosen randomly by the Logistic mapping which enhanced the security and flexibility of the proposed algorithm.

II. THE PREDICTION DIFFERENCE OF INTRA_4×4

Intra prediction is a unique technology in H.264/AVC, which can reduce the spatial redundancy effectively and achieve a higher compression rate. During the intra prediction, the pixel values of current block are calculated by the boundary pixel of adjacent blocks. In H.264, Intra prediction can be divided into intra_4×4 prediction and intra_16×16 prediction according to the size of predicting block. Generally speaking, intra_16×16 prediction including 4 kinds of prediction modes, is chosen for the smooth areas in video frame, while intra_4×4 prediction including 9 kinds of prediction modes is suitable for detailed areas. The specific process of prediction is described in literature [9].

Figure 1 is the predicting method of intra_4×4 prediction, where A~M in the figure are reference pixels. In order to choose the best mode from the nine modes, H.264/AVC uses the rate-distortion model based on the algorithm of Lagrangian optimization, namely:

$$best \bmod e = \{ i \mid \min \{ J_i \}, i \in S \} \qquad (1)$$

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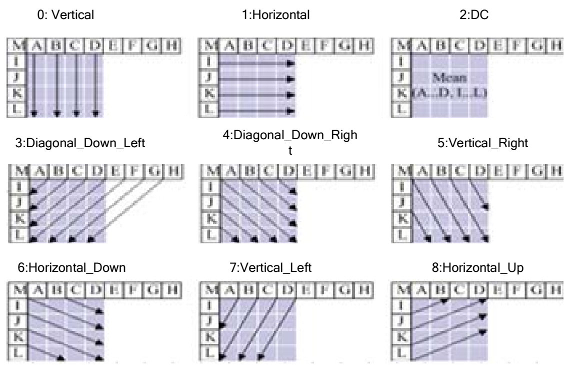


Fig.1 the generation rule of I4-modes

Where, S denotes the set of I4-modes, $best\ \mathrm{mod}\,e$ denotes the best mode of current 4×4 block, and J_i is the Lagrangian cost function defined as follows:

$$J_i = \text{Distortion} + \lambda_i \times Rate \tag{2}$$

Where λ is a Lagrangian parameter, Distortion denotes the distortion between predicting block and original block, and Rate is the number of bits to encode the 4×4 block.

In H.264/AVC, there is no distinct difference among these modes of intra_4×4. Because they are predicted by the neighboring pixels A~M. what is different is the predicting direction. Each predicting direction will use a different weighting factor, for instance, mode 2 is DC prediction where all the pixels are calculated by (A+B+C+D+I+J+K+L)/8. In general, the littler the direction difference(for instance mode 0 and mode 7), the more similar the weighting factor. The predicting difference obtained is also littler. In order to assess the difference of prediction among these modes accurately, a objective evaluation indicator, SAD_{ij} is introduced, namely:

$$SAD_{ij} = \sum_{m,n} \left| P_i(m,n) - P_j(m,n) \right| \tag{3}$$

Where $P_i(m,n)$ and $P_j(m,n)$ are the predicting pixels by mode i and mode j .Table 1 shows the SAD_{ij} among these modes, which is obtained based on more than 100000 samples of 4×4 block from ten testing sequences. As shown in the table, there is no significant shift for SAD_{ij} during the change of mode. Besides, the SAD_{ij} is littler between modes provided with similar predicting direction.

Tab1 the prediction difference among I4-modes

mode	0	1	2	3	4	5	6	7	8
0 (Vertical)	0	281	166	156	182	133	225	111	288
1 (Horizontal)	281	0	156	296	179	220	128	279	84
2 (DC)	166	156	0	184	126	131	130	159	156
3 (Dia_Down_Left)	156	296	184	0	207	175	238	63	294
4(Dia_Down_Right)	182	179	126	207	0	75	76	182	185
5 (Vertical_Right)	133	220	131	175	75	0	135	144	223
6(Horizontal_Down)	225	128	130	238	76	135	0	218	141
7 (Vertical_Left)	111	279	159	63	182	144	218	0	279
8 (Horizontal_Up)	288	84	156	294	185	223	141	279	0

III. THE PROPOSED ALGORITHM

The proposed algorithm hides secret information into the macroblock provided with the mode of intra_4×4(I4MB) by modulation the I4-modes according to the rule of mapping between these I4-modes and the hidden bits.

A. *The rule of mapping*

In order to construct the rule of mapping, the I4-modes space S is needed to divided into two subset defined as subset M and N. M and N should meet the following conditions:1) 1).M⊆S and M≠Φ, N⊆S and N≠Φ; 2). M∩N=Φ and M∪N=S. The mapping rule between binary bits and I4-modes can be expressed as:

$$\mathrm{mod}\,e \in \begin{cases} M & \text{if } \mathrm{w_k} = 0 \\ N & \text{if } \mathrm{w_k} = 1 \end{cases} \tag{4}$$

Where mode represents the coding model of current 4×4 block, w_k denotes the hidden data. M and N should have a similar prediction effect to ensure the invisibility of hidden information. The proposed scheme divides the I4-modes into two groups by means of the prediction difference of intra_4×4 to effectively implement information hiding. The optimal grouping can be obtained by the following expression:

$$\mathrm{P} = \min\left\{ \left| \sum_{i,j \in M} SAD_{ij} - \sum_{i,j \in N} SAD_{ij} \right| \right\} \tag{5}$$

The calculated result is shown as following:

$$\begin{cases} M = \{0,1,3,8\} \\ N = \{2,4,5,6,7\} \end{cases} \tag{6}$$

B. *The choice of hidden position*

In this paper, the logistic mapping rules are employed to randomly select the hidden locations to keep hidden data secure. Logistic mapping is a nonlinear system which can produce chaos。The mapping function can be described as follows:

$$x_{k+1} = \mu x_k (1 - x_k) \tag{7}$$

Where μ represents the branch parameter. It is said under the research of Chaotic dynamical systems that logistic mapping shows the chaotic state when $3.566945 < \mu \leq 4$. Namely, the sequence generated by the initial value x0 is non-cyclical, non-convergent, and greatly dependent on the initial value under the action of the logistic mapping.Based on the mapping function above, the hidden position can be get as follows:

Steps1: Number the 4 × 4 luminance block in I4MB by the means of Figure 2, and give the logistic sequence an initial value to generate a chaotic sequence with the length being 16, which is called S.

1	2	5	6
3	4	7	8
9	10	13	14
11	12	15	16

Fig.2 the number of 4×4 luminance block

Step2: Multiply each element in S by 16 and round it down, which can get an integer sequence S' ranging from 1 to 16.

Step3: Randomly select n unequal elements From the S' as the hidden location of the 4 × 4 luminance block.

C. Information embedding

Based on the analysis above, the proposed information hiding algorithm can be implemented as follows:

Step1: Generate a binary sequence W_k by the way of spread spectrum.

Step2: If the current macroblock is I4MB, embedding hidden information according to the following expression; otherwise no hiding is performed in this macroblock.

$$\text{mod}\,e = \{i \mid \min\{J_i\}, i \in V\} \tag{8}$$

where

$$V = \begin{cases} M & \text{if } w_k = 0 \\ N & \text{if } w_k = 1 \end{cases} \tag{9}$$

Step3: Repeat step 2 until hidden data are over or the sequences of video are end.

D. Information extracting

The extraction of hidden information is simple and rapid in this paper. It can be achieved by means of merely decoding the mode of I4MB, rather than the original media and the complete video decoding. The specific steps can be described as follows:

Step1: If the current macroblock is I4MB, determine the embedded position accord to the logistic sequence; otherwise go to step3.

Step2: If the current 4×4 block is hidden block, extracting hidden information according to the following expression; otherwise go to next step.

$$w_k = \begin{cases} 0 & \text{if mode} \in \text{M} \\ 1 & \text{if mode} \in \text{N} \end{cases} \tag{10}$$

Step 3: Repeat the step1 until the extraction is complete or the sequences of video are end.

IV. EXPERIMENT ANALYSIS

The proposed algorithm has been implemented in the H.264/AVC reference software JM11.0[10]. Eight video sequences with the resolution of QCIF(176×144) are used in the test, including Salesman 、 Foreman 、 Carphone 、 Container、Mother-daughter、News、Highway、Silent. The video frames are encoded in the fashion of IBPBPBP…style to comply with the main profile. The nmber of frames is 100 for each encoded sequences.

A. The effect on video quality and rate after information hiding

In order to effectively evaluate the performance, the proposed algorithm introduces three objective indicators, capacity of information hiding(C), change of bit-rate(BRI) and change of PSNR. The BRI and PSNR are defined as follows:

$$BRI = R' - R \tag{11}$$

$$PSNR = 10\lg \frac{\max(I_{ij}^{\;2})}{\frac{1}{MN} \times \sum_{i}^{M}\sum_{j}^{N}(I_{ij} - I_{ij}')} \tag{12}$$

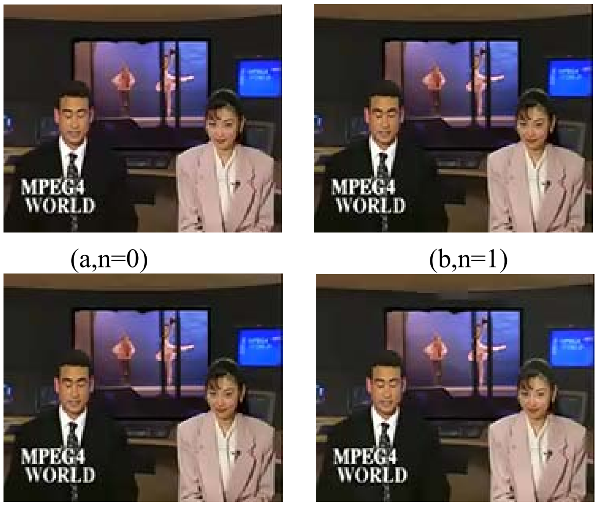
Where R' and R are the bit-rate after and before information hiding respectively, M and N are the height and width of video frame respectively, I_{ij} and I_{ij}' represent the original pixel and the processed pixel .

The C, BRI and change of PSNR are reported in table2 for eight different test sequences when n are equal to 1, 3 and 5. As can be seen from the table, there are only minor changes in bit-rate and PSNR after information hiding, that is, embedding data does not affect the bit-rate of video and quality of video. This is mainly because the hiding of information is performed by modulating the I4-modes. The modulation of I4-modes merely brings about different prediction value, which will create different predicting residuals that will be further processed by transformation of DCT, quantization, entropy coding. The ultimate quality of video is decided by the ensemble of all these steps. Consequently, no obvious change in bit-rate as well as in the quality of video is expected in the proposed algorithm. In addition, hiding capacity will become large with the increase of n. when the capacity become larger, the bit-rate of video will also increase a little bit.

Figure 3 illustrates the perceptual quality of video frame performed with information hiding. The example frame is the 6th I frame for the sequence News. As shown, there is no distinct difference among them.

Tab.2 the experiment results for eight test sequences

Sequence	n=1			n=3			n=5		
	C(bit)	I(dB)	BRI(bps)	C(bit)	I(dB)	BRI(bps)	C(bit)	I(dB)	BRI(bps)
Container	635	-0.01	0.17	1920	+0.01	0.74	3205	-0.01	0.99
Highway	766	+0.02	0.18	2310	+0.01	0.52	3850	0	0.81
News	850	-0.01	0.11	2550	+0.01	1.23	4260	-0.01	2.12
Carhhone	833	-0.01	0.58	2502	0	1.21	4175	0	1.87
Mother-daughter	787	-0.01	0.35	2461	-0.01	0.92	3950	-0.02	1.55
Salesman	952	0	0.51	2856	0	1.26	4775	-0.01	2.01
Slient	962	0	0.60	2895	+0.02	1.74	4830	+0.01	1.98
Foreman	936	+0.01	0.52	2808	-0.01	1.53	4650	-0.01	2.23



(a,n=0) (b,n=1)

(c,a=3) (d,a=5)

Fig.3 the video frame before and after information hiding

B. Security analysis

The propose algorithm has a good security. This is mainly because 1). The hidden position is randomly selected by the Logistic sequence. It is extremely difficult for attacker to determine the hidden location without knowing the initial value x_0 of Logistic sequence; 2). By introducing the rate-distortion cost during the step of the modulation of mode, the proposed scheme has a less influence on quality of video and bit-rate of video, which will enhance the difficulty of Steganalysis;3). The mode of I frame is highly important information for compression bit-stream of H.264 and has a good reliability during the process of transmission, which will guarantee the correct extraction of secret information.

V. CONCLUSIONS

In this paper, a scheme of information hiding based on the prediction difference of intra_4×4 is proposed. The process of information hiding is the process of modulation of I4-modes. The embedding algorithm considers the code standard of H.264/AVC and introduces rate-distortion cost when information is embedded, which reduces the impact on the quality of video and bit-rate of video after information hiding. It is shown from the experiment that the hiding capacity is larger and information retrieval is simple and fast, requiring neither original media nor complete video decoding. There is little effect on the quality of video and bit-rate of video after information hiding.

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