A Novel Information Hiding Algorithm Based on Grey Relational Analysis for H.264/AVC

Yingnan Zhang
Key Laboratory of Network&Information Security of PAPF, Engineering University of the PAPF
Xi'an, China, 710086
zyn583@163.com

Minqing Zhang
Key Laboratory of Network&Information Security of PAPF, Engineering University of the PAPF
Xi'an, China, 710086
api_zmq@126.com

Jingjing Wang
Key Laboratory of Network&Information Security of PAPF, Engineering University of the PAPF
Xi'an, China, 710086
344505421@qq.com

Ke Niu
Key Laboratory of Network&Information Security of PAPF, Engineering University of the PAPF
Xi'an, China, 710086
niuke@163.com

***Abstract*—On the basis of analyzing some existing video steganographic algorithms and find out some problems, like have large impact on the video quality and bit rate, so we propose a new algorithm based on grey relational analysis combining with the partition modes features of the H.264/AVC. The algorithm firstly compute the grey relevancy of blocks and judge if it has texture features. Then perform DCT on the current frame. Finally choose the proper capacity based on partition modes and embed information in DCT numbers. The experimental results show that the proposed algorithm has little impact on the video quality and bit rate, also has the advantages that anti-noise, anti-filter and high capacity information hiding.**

Keywords—grey relational analysis; video; information hiding; partition modes; H.264/AVC

I. INTRODUCTION

Information hiding, also be called steganography is a technique that hide information in the public digital media and then achieve covert communication. Today steganography algorithms based on image has made a lot of achievements, but because of the limited capacity of the digital image, the secret information's capacity to embedded is also restricted. Compared with digital image, video has large capacity, more redundancy, high communication quality, robustness, et al, so the study of steganographic methods based on video for H.264/AVC has become one of the new hot spots.

Hua [1] has proposed a video steganography algorithm based on H.264/AVC, the algorithm can be implemented to achieve embedding and extracting, but the algorithm is weak in anti-attack. Langelaar [2] has proposed a mechanism for the compressed video stream, the advantage of this algorithm is that it only need part of the coding stream, then they can achieve higher data embedding capacity, but the algorithm weak in anti-steganalysis detection. Ma [3] has proposed a novel algorithm based on H.264, it improves the visual quality, but the embedding efficiency and embedding capacity needs to be improved. He [4] has proposed a new method based on motion vector, but the capacity of embedding is limited. Zhang [5] has proposed robust video watermarking algorithm for H.264/AVC based on texture feature, it has little impact on the video quality and bit rate, but it has little capacity to embed. Liu [6] has proposed a method based on macro-block segmentation, the bit rate increase is very low, but it is weak in the anti-steganalysis detection. Above all, the steganography algorithms based on video for H.264/AVC exist some problems such as the large impact of video quality and bit rate, weak in anti-attack, less capacity of embedding and so on.

To solve this problems, we propose a novel video information hiding algorithm based on grey relational

Project supported by the National Science Foundation of China: Theory research on extracting and optimizing feature of image steganalysis (Grant No.61379152), and the National Science Foundation of China: Cross-Domain Human Action Recognition by Knowledge Transfer (Grant No.61403417).

978-1-4673-7695-2/15 $31.00 © 2015 IEEE
DOI 10.1109/INCoS.2015.48

analysis. It uses the grey relational model to choose relatively insensitive part in carrier as the region to embed, combining with H.264 characteristics to change the embedding capacity, and then embed secret information in the DCT coefficients. Experimental results show that the algorithm has less impact on the video quality and bit rate, and has large capacity to embed.

II. PRELIMINARIES

A. Partition modes

In H.264 coding standard, each macro-block(16×16 pixel) has 4 modes to part as shows in Figure 1: 16×16 、 16×8 、 8×16 、 8×8 . As shows in Figure 2, when using the 8×8 as the split mode has further 4 sub-macro-block modes: 8×8 、 8×4 、 4×8 、 4×4 . Such segmentation improves correlation between each macro-blocks.

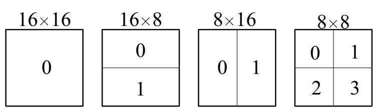

Fig. 1. Macro-block level model

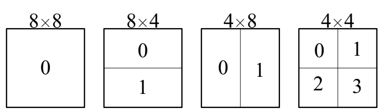

Fig. 2. Sub-macro-block level mode

H.264/AVC encoder uses the model based on Lagrangian rate-distortion optimization, which traverses all of the current macro-block modes and calculating each Lagrangian cost function to determine the optimal macro-block partition mode selection. Lagrangian formula is as follows:

$$J_{MODE}(S_i, I_i \mid Q, \lambda_{MODE}) = D_{REC}(S_i, I_i \mid Q) + \lambda_{MODE} \times R_{REC}(S_i, I_i \mid Q) \quad (1)$$

The partition mode is the current mode which make the cost function the minimum value. λ_{MODE} is the Lagrangian parameter, $D_{REC}(S_i, I_i \mid Q)$ is the bit rate of the encoded bit stream, $R_{REC}(S_i, I_i \mid Q)$ is the distortion after coding, S_i represents the No. i macro-block, I_i is the current coding mode, Q is the quantization step size. That H.264/AVC calculates the current block cost function, and select the best mode according to the cost function, and mark it [7]. We mainly take the more symmetrical macro-block 4×4 、 8×8 and 16×16 as modulating block.

B. Grey relational analysis

Grey relational analysis is a method of analyzing system to analysis various factors, is an important branch of grey theory system [8].

a. Grey correlation coefficient

Set the reference sequence is $x_0 = \{x_0(k) \mid k = 1, 2, \cdots, N\}$, comparative sequence is $x_i = \{x_i(k) \mid k = 1, 2, \cdots, N\}$, Where N represents the number of sequence. Define the correlation coefficient formula as follows:

$$\xi_{i,0}(k) = \frac{\min_i \min_k |x_0(k) - x_i(k)| + \rho \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \rho \max_i \max_k |x_0(k) - x_i(k)|} \quad (2)$$

$\rho \in [0,1]$ is the distinguish factor. $\xi_{i,0}(k)$ used to reflect the similarity of comparative sequence x_i and reference sequence x_0 at the same point.

b. Grey correlation degree

Grey correlation degree formula is as follows:

$$r(x_i, x_0) = r_{i,0} = \frac{1}{N} \sum_{i=1}^{N} \xi_{i,0}(k) \quad (3)$$

$r(x_i, x_0)$ reflects the whole similarity of comparative sequence x_i and reference sequence x_0 at the same point.

III. PROPOSED SCHEME

A. Select modulation regions

Information hiding algorithms generally hide secret information in non-smooth regions. We use grey correlation to determine whether the region is smooth or not.

When we get the partition modes of current block, we can do the steps as follows (we use $X \times X$ $(X = \{4,8,16\})$ represents the block we choose):

(1)Confirm comparative and reference sequence:

Smooth region is the region that there is no difference in pixel values, it can be assumed that the pixel values of ideal smooth area are all the same.

a. Comparative sequence: each pixel value of the $X \times X$ block scan by Zigzag.

b. Reference sequence: we use ideal smooth areas reference sequence. In our algorithm, we taking the average of the whole pixels of block of the comparison sequence.

(2) Select modulating regions:

We use formula (2) and formula (3) to calculate out the grey correlation coefficients of current block, with a threshold $T(T \in (0,1))$ to select the modulating regions, and then label these.

Generally, the threshold may vary with the amount of information to be embedded, the number of frames and the size of video sequence.

B. Embedding algorithm

Step 1 Pretreating the secret information. Encrypting secret information, reducing the correlation between the information and improving the safety;

Step2 DCT the frames, and from III.A, we can get the region we want hide information in, and then scan this DCT coefficients by Zigzag into a one-dimensional array;

Given:

l : the length of the vector to be embedded;

T : Quantization threshold;

$round(\bullet)$: Rounding operator (when its decimal lesser than 0.4 and big than 0, change decimal to 0; when its decimal bigger than 0.5 and lesser than 1, change decimal to 0 and add 1;);

Modifying the front 8 coefficients to 8-dimensional vector, $\boldsymbol{C} = (c_0, c_1, c_2, c_3, c_4, c_5, c_6, c_7)$;

(1) $l = |\boldsymbol{C}| = \sqrt{\sum_{j=0}^{7} c_j^2}$

(2) $l' = \begin{cases} \left(round\left(\frac{l}{T}\right) \pm \alpha \right) \cdot T, & if \quad M(i) = 1 \\ \left(round\left(\frac{l}{T}\right) \right) \cdot T, & if \quad M(i) = 0 \end{cases}$

$M(i)$ represents of embedding bit, l' represents the modified vector length, $\alpha(\alpha \in (0{,}0.4))$ is to ensure the randomness of the embedding process;

(3) $\boldsymbol{C}' = \frac{l'}{l}\boldsymbol{C}$; Put the vector $\boldsymbol{C}'$ back into DCT blocks;

Step 3 Determine the embedding amount based on the mode flag. 4×4 block embeds 1 bit, 8×8 block embeds 4 bits, 16×16 block embeds 16 bits;

Step4 Repeat **Step 2-Step 4** until the embedding is completed.

C. Blind extracting algorithm

We present a blind extraction algorithm without the original carrier:

Step 1 First reconstruct stego-carrier, judge the partition modes, labeling out 8×8 、 4×4 and 16×16 blocks; calculating out grey relational degree again and judge according to the standard of embedded algorithm and mark it again;

Step 2 DCT the video frame, scan DCT coefficients which mark in **Step 1** by Zigzag, and put it into a one-dimensional array;

Step 3 Take the seven low-frequency coefficients converted to 8-dimensional vector $\boldsymbol{S}$;

(1) $\boldsymbol{S} = (s_0, s_1, s_2, s_3, s_4, s_5, s_6, s_7)$

(2) $L = \sqrt{\sum_{j=0}^{7} \bar{s}_j^{\,2}}$

(3) $I = \frac{L}{T} - round\left(\frac{L}{T}\right)$

(4) $M(i) = \begin{cases} 1, & if \quad I \neq 0 \\ 0, & if \quad I = 0 \end{cases}$

Then 4×4 block extract 1 bit， 8×8 block extract 4 bits， 16×16 block extract 16 bits；

Step 4 Repeat **Step 3-Step 4** until the secret information extraction is completed

Step 5 Inverse pretreatment to extract information to get the secret information.

IV. EXPERIMENT ANALYSIS

Our experiment is based on X.264, the video sequence is downloaded from the Internet website “media.xiph.org”. Each sequence is 15 frames/s, bit rate is 396kbit/s. In our algorithm, the grey distinguish coefficient ρ is 0.25. Secret information is the grey image “lena.bmp”.

A. Analysis of invisibility

The original and embedded Grandma sequence’s No.30 frame is shows in Figure 3. We can catch that no significant difference with them. Figure 4 shows a comparison of the original and extracted secret image, we can see the secret information after extracting appears only little points at somewhere, but the image is still clearly identified.

(a) original frame (b) frame after embedding

Fig. 3. Comparison

(a) original image (b) extracting image

Fig. 4. Figure 4 Comparison

PSNR value of the Bridge-Far, City, Claier, Container, Grandma, Hall, and Mobile sequences after embedding secret information and compared with the original video sequence are show in Figure 5, and the results showed that the decrease is small after embedding, the average decline of PSNR value is about 1.323dB.

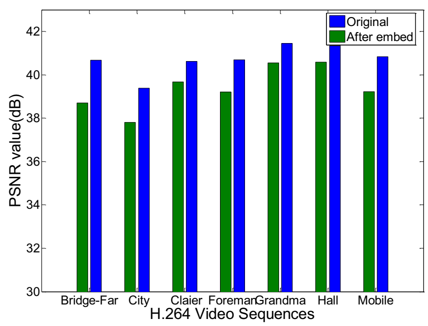

Fig. 5. The average decline of PSNR value of the components

Since Grandma sequence is rich in texture blocks, there are also a lot of smoothing blocks, so we calculate pre-30 frames' PSNR value of it. Figure 6 shows the PSNR value of pre-30 frames of Grandma after embedding secret information, it can be seen, the impact of the first frame is about 2.27dB, the impact of the No.16 frame of about 1.89dB, the others has little effect.

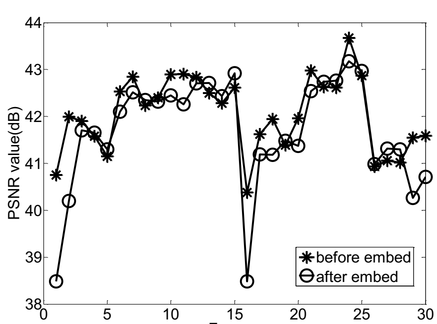

Fig. 6. Comparison the PSNR before and after embed of Grandma

B. Steganographic capacity

Figure 7 shows the embedding capacity of our algorithm, He's algorithm and Ma's algorithm.

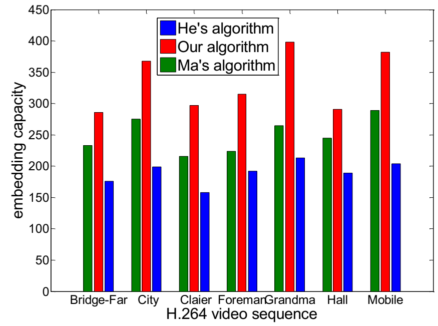

Fig. 7. Compare steganographic capacity

As can be seen from the experiment, our algorithm has larger embedding capacity.

C. Bit Rate analysis

Detecting the bit rate increase (BRI) of our algorithm after embed. BRI formula is as follows:

$$BRI = \frac{rate' - rate}{rate} \times 100\% \tag{4}$$

$rate'$ represents the one after embed, $rate$ represents the original one.

The result show in Table I:

TABLE I. BIT RATE INCREASE

Video sequences	Frame numbers	Before embedding(Kb)	After embedding(Kb)	BRI (%)
Bridge-Far	2101	78000	79458	1.87
City	150	5569	5735	2.98
Claier	494	18340	18642	1.65
Forman	300	44550	45485	2.10
Grandma	870	32299	32773	1.47
Hall	300	11138	11386	2.23
Mobile	300	44550	45592	2.34

As can be seen from Table I, all the BRI of components are lower than 3%, proving that the impact on bit rate is small after using our algorithm to embed.

V. CONCLUSION

Through these studies, we propose a DCT-domain video information hiding algorithm based on grey relational analysis standard combining H.264 compression characteristics. The algorithm uses the grey relational model to choose relatively insensitive part in cover video as the region to embed secret information, combining with H.264 coding standard‘s characteristics to change the embedding capacity, then embeds secret information in the low numbers of DCT coefficients. Experimental results show that the algorithm have a large capacity to embed, and has little impact on the video quality and bit rate.

References

[1] G. L. Hua, Z. B. Li, B. Feng. Low frequency steganography algorithm for H.264/AVC [J]. Journal on Communications, 2013, 34(Z2), 47-50.

[2] G. C. Langelaar, R. R. Lagendijk. Optimal differential energy watermarking of DCT encode images and video [J]. IEEE Transactions on Image Processing, 2001, 10(1): 148-158.

[3] X. J. Ma. The Research on Video Data Hiding Algorithms Based on H.264/AVC [D]. Wuhan: Huazhong Univercity of Science and Technology, 2010.

[4] X. S. He, Z. Luo. A Novel Steganographic Algorithm Based on the Motion Vector Phase [C]. International Conference on Computer Science and Software Engineering CSSE. 2008. 359: 822-825.

[5] W. W. Zhang, R. Zhang, Y. J. Liu , et al . Robust Video Watermarking Algorithm for H.264/AVC Based on Texture Feature [J]. Journal on Communications, 2012, 33(3), 82-89.

[6] C. H. Liu, O. T. Chen. Data Hiding in Intra Prediction Modes of H.264/AVC [J]. IEEE Press. 2008, 3025-3028.

[7] H. J. Bi. A New Generation of Video Compression Standard---H.264/AVC [M]. Beijing: Posts & Telecom Press, 2005, 110-111.

[8] J. L. Deng. Basic Method of Grey System Theory [M]. Wuhan: Huazhong University of Science and Technology Press, 2005.