3D-HEVC Deep Video Information Hiding and Secure Transmission Method

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Abstract. HEVC information hiding algorithm and DCT/DST video information hiding algorithm used in the past have poor hiding effect and low security transmission efficiency. In view of this phenomenon, a new 3D-HEVC deep video information hiding and secure transmission method is designed. According to the coding principle of single depth frame, the multi-view color and depth video feature regions are divided, and then the information hiding process is designed. On this basis, the encryption key is used to realize the secure transmission of information. The experimental results show that the method has good hiding effect and high safety transmission efficiency, which proves that it has good hiding and transmission effect.

Keywords: 3D-HEVC deep video · Information hiding · Secure transmission · Encryption key

1 Introduction

3D-HEVC video can provide three-dimensional, telepresence and interactivity, so it has been widely concerned. MVD is the main representation format of 3D-HEVC video scene, which enables the decoder of 3D-HEVC video system to draw virtual viewpoint by depth map based rendering technology.

In order to compress MVD efficiently, we usually need to expand 3D on the basis of efficient video coding, and develop 3D-HEVC coding standard [1]. With the growing maturity of multimedia and network technology, 3D video acquisition and processing become easier, and the resulting information security problems become increasingly serious. Information hiding technology is an effective way to solve this problem [2].

At present, the information hiding algorithm of plane color video has been relatively mature, mainly divided into the original domain information hiding algorithm and the information hiding algorithm based on the encoding and decoding platform. In the video information hiding algorithm based on codec, secret information is directly

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embedded in the video coding process. Compared with the original video information hiding method, the secret information extracted in the decoding process can greatly reduce the degradation of the decoded video quality. HEVC is the latest video coding standard. Under the same coding quality, it can save 50% bit rate compared with H.264/AVC [3]. To this end, some scholars proposed an information hiding algorithm based on HEVC efficient motion vector space coding, which can embed a certain amount of information, but has a certain influence on the overall bit rate. Another scholar proposed an HEVC video information hiding algorithm based on DCT/DST coefficient without error drift, but under the condition of high bit rate, the information hiding capacity is small.

In order to safely transmit secret information in 3D video, a 3D-HEVC depth video information hiding algorithm based on multi-view video features is proposed for the latest coding and compression standards. First, map the texture feature area of the color video to the corresponding depth video, and then divide the depth video according to the edge characteristics of the depth video; then, according to the influence of different areas on the coding efficiency, the maximum coding unit (The QP value of LCU) is embedded in the secret information; finally, the modified QP value is used for encoding and compression, and the video information is transmitted.

2 3D-HEVC Depth Video Information Hiding Algorithm

3D-HEVC coding framework is applied to multi view video depth (MVD) system to realize video coding, decoding and multi view rendering, and provide users with real stereo vision [4]. However, in the process of multi view rendering, the accuracy of depth map boundary will directly affect the position of 3D warping, resulting in the decline of virtual view quality and user experience. From this point of view, the influence of different areas of depth video on the visual effects of virtual viewpoints is considered. Under the condition that the rendering quality and the bit rate are not changed much, the secret information is embedded in the depth map by using the characteristic of the variation of coding quantization parameters [5].

2.1 Coding Principle of Single Depth Intra Mode

The depth video contains a large number of flat areas, and the pixel values in the area are similar or equal. For the characteristics of depth video, if the color video coding prediction mode is still adopted, it is difficult to achieve the purpose of efficient compression [1]. Therefore, the 3D-HEVC coding standard has added a single-depth intra mode specifically for the flat area of depth video. Single-depth intra mode is a CU-level coding mode. The current CU block constructs a pixel candidate list based on the neighborhood reconstruction information, traverses the pixels in the list to calculate the

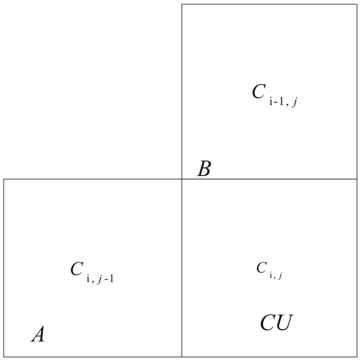


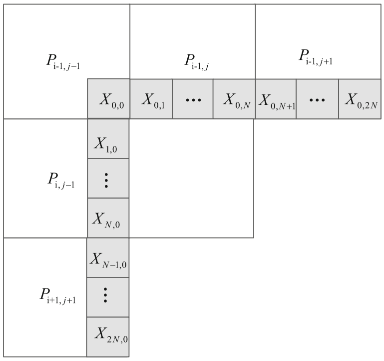
Fig. 1. Neighborhood information used in building candidate list

rate distortion cost, and calculates the index of the pixel with the least cost in the candidate list the value is written into the code stream without the need for transformation and quantization. The decoder directly finds the corresponding reconstructed pixel in the candidate list according to the index value to reconstruct the current block [6].

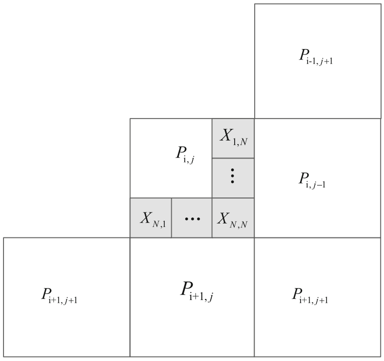
Figure 1 shows the neighborhood information used to build the candidate list. In Fig. 1, the middle pixels of the reconstructed Cu block on the left and top are A and B respectively, and the traversal order is from A to B.

In the single depth intra mode, the corresponding reconstruction pixel is selected according to the index value, and the current Cu block is reconstructed from this pixel. Therefore, when the pixel values in the candidate list are equal, using the embedding information to modulate the index value of the pixel in the current list will not cause the embedding error of the current Cu block, because the final selected reconstruction pixel has not changed [7].

In order to further improve the embedding amount of information, the situation that the pixel values of the candidate list are not equal is analyzed. The prediction reference relationship between the current Pu block and the neighborhood block is shown in Fig. 2.



(a) Reference pixel for intra prediction of current PU block



(b) The current PU block is used as a reference pixel for intra prediction in subsequent blocks

Fig. 2. The prediction reference relationship between the current PU block and the neighboring block

Figure 2 shows the prediction reference relationship between the current prediction unit (PU) block and the neighborhood block. Figure 2(a) is the reference pixel of the current Pu block during intra prediction. The distortion of the neighborhood pixel $\{X_{0,i}\}_{i=0.1,\ldots,N}/\{X_{i,0}\}_{i=0.1,\ldots,N}$ ($N \times N$ is the size of the Pu block) will affect the prediction of the current Pu block, resulting in error drift. Figure 2(b) is the reference pixel position of the current PU block used for prediction in the frame of the subsequent blocks. The last row and the last column of the current PU block can both be used as the reference pixel of the subsequent blocks [8].

2.2 Multi-viewpoint Color and Depth Video Feature Area Division

Depth video is mainly used to draw virtual viewpoint, and the edge region in depth image has a great influence on the quality of still image. At the same time, the depth video is distorted in the texture region where the corresponding position is color video, which has a greater impact on the quality of rendering virtual viewpoint [9, 10].

Considering the above factors, the depth video is divided into four categories according to the characteristics of color and depth video, namely, the color video texture region (CTR) corresponding to the depth video edge, which is called tder; the color video texture region corresponding to the depth video smooth region (DSR), which is called TDSR; and the color video flat region corresponding to the depth video edge (DER) is fder; the flat area of color video corresponding to depth video smoothing (DSR) is fdsr [11].

The specific division idea is: for depth video region, in order to improve the accuracy of depth edge division, an adaptive region edge extraction method is adopted. Firstly, the gradient value of each pixel is calculated by Sobel operator, and then the discrimination threshold is obtained adaptively through the histogram characteristics of the gradient value, and finally the Der and DSR regions are obtained. For color video region, Canny operator is used to obtain pixel gradient, and the threshold and gradient are compared to determine CTR and CFR region [12]. The specific principle is as follows:

(1) Deep video edge detection
The depth gradient value $\nabla g(x, y)$ is obtained by using template convolution to calculate the horizontal and vertical superposition. The specific calculation formula is as follows:

$$\begin{gathered} \nabla g(x, y) = \sqrt{g_x^2(x, y) + g_y^2(x, y)} \\ g_x = a_x \times D \\ g_y = a_y \times D \end{gathered} \tag{1}$$

In formula (1), g_x and g_y represent the horizontal and vertical gradient vectors of the pixel, D represents the depth value matrix, and a_x and a_y represent the horizontal and vertical gradient operators, respectively.
At present, the depth video is mainly obtained by depth estimation software, and the estimation is not accurate [13]. In order to remove the false boundary in the gradient image, the gradient histogram is used to adaptively obtain the discrimination threshold, and finally the depth boundary is detected. Assuming that there is a dual pattern distribution in the histogram distribution of depth gradient, there must be an optimal threshold to satisfy the segmentation of the depth region. By using the intra group equilibrium measure variance, an appropriate dividing line is determined to minimize the weighted sum of intra group variance.

(2) Color video texture detection
The color area division method generally uses the Canny operator. First, Gaussian smoothing filtering is performed on the color image to eliminate Gaussian noise and improve the stability of edge detection. Second, calculate the gradient value of each pixel. Then, non-maximum value suppression is performed to extract the

gradient point with the maximum extreme value as the boundary. Because the traditional single-threshold method will lose some real edges, double-threshold detection is used to select the final boundary position from the gray boundary. The calculation formula for dual threshold detection is as follows:

$$\begin{cases} C_e(x,y) = \\ C_2(x,y) \ \text{if} \ C_1(x,y) = 0 \cup C_2(x,y) = 255 \\ \exists(x,y) \in N_{c_1} \\ C_1(x,y) \quad \text{if} \ C_1(x,y) = 255 \\ 0 \quad \text{other wise} \end{cases} \tag{2}$$

Among them, $C_1(x, y)$ and $C_2(x, y)$ are the edges with high threshold and low threshold to obtain non maximum suppression results, respectively. The position with a value of 255 indicates that there is an edge, and the place with a value of u indicates a flat area. N_{c_1} is the four neighborhood region of high threshold edge detection. The expression of color video partition is as follows:

$$\begin{cases} \text{if} \ C_e(x,y) = 255 & C(x,y) \subseteq \text{CTR} \\ \text{if} \ C_e(x,y) = 0 & C(x,y) \subseteq \text{CFR} \end{cases} \tag{3}$$

where $C(x,y)$ represents the pixel value of the color video region corresponding to the (x,y) coordinate region.

(3) Depth video region division results

The maximum coding unit (LCU) of 3D-HEVC is the pixel block of 64 × 64. according to the characteristics of coding structure, the pixel value area of 64 × 64 is divided as the basic unit. Combined with the color video region segmentation, the final depth video region segmentation is as follows

$$Rs = \begin{cases} \theta_1 & \text{CTR} \cap \text{DER} \\ \theta_2 & \text{CFR} \cap \text{DER} \\ \theta_3 & \text{CTR} \cap \text{DSR} \\ \theta_4 & \text{CFR} \cap \text{DSR} \end{cases} \tag{4}$$

Among them: Rs is the discriminant factor, which is used to determine what kind of region to divide, and the image region Rs is divided.

2.3 Hiding Method

The information hiding process is shown in Fig. 3.

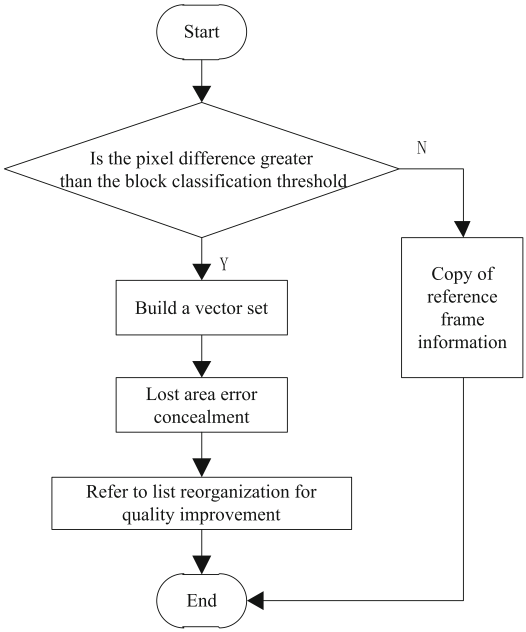


Fig. 3. Flow chart of information hiding

The specific steps of the hiding method are as follows:

Step (1): according to the coordinates of the pixel points of the image missing block, the co bit block B_1 in the forward reference frame and the co bit block B_2 in the backward reference frame are obtained, and the size of the co bit block is 64×64.

Step (2): Take the absolute value of the difference between the average values of the pixels of the two co-located blocks B_1 and B_2. When the average pixel difference Th is greater than the threshold 1, it is judged that the current lost block is a moving block, otherwise, it is judged as a stationary block. If it is judged that the type of the lost block is a static block, use the co-located block in the forward reference frame or the co-located block information in the backward reference frame to fill the current missing block in the image for recovery; if the type of the lost block is judged to be a moving block, Adopt the method based on vector compensation to recover; and then improve the quality of the lost blocks with poor final recovery performance.

The specific steps of restoration based on vector compensation are as follows:

Step (a): build the motion sharing vector.

After scaling the available motion vectors of the same bit block in the texture image, the set of vectors to be selected is added; if the corresponding same bit block is an intra coding block, the average value of the motion vectors of the adjacent blocks that are not zero is taken as the current motion vector to be selected:

$$MV_{\text{texature}} = \frac{MV_t}{R} \tag{5}$$

In formula (5), MV_{texature} is the final optimized motion vector, MV_t is the motion vector directly obtained in the texture map, and R is the zoom ratio.

Step (b): construct the airspace vector set.

Select the motion/disparity vectors of the lower left block 0, the left block 1, the upper left block 2, the upper block 3, the upper right block 4, and the lower block 5 of size 4 × 4 to construct the spatial vector set, and the corresponding displacement vector set is $\{\mathrm{SV}_0, \mathrm{SV}_1, \mathrm{SV}_2, \mathrm{SV}_3, \mathrm{SV}_4, \mathrm{SV}_5\}$; If the selected block is lost, the motion vector information of the block will be discarded.

Step (c): Global parallax vector.

Calculation method of global parallax vector value:

$$DV_g = \frac{1}{N}\sum_{i=0}^{N} DV_i \tag{6}$$

Among them, N is the number of blocks with a size of 8 × 8 and disparity vectors, and DV_i is the disparity vector value of the i-th block 8 × 8; the aforementioned motion sharing vector, 5 spatial vectors, and a global vector constitute a candidate vector set.

Step (d): Rebuild the lost block.

Select a certain candidate motion/disparity vector from the candidate vector set, and use the motion/disparity vector compensation method to fill the hole in the pixel position in the missing block;

Step (e): Calculate the matching degree of the outer boundary.

The weighted outer boundary matching algorithm calculates the matching degree Dobma between the outer boundary of the motion/disparity compensation block and the outer boundary of the lost block in the reference frame. According to the weighted outer boundary matching algorithm, the depth map outer boundary matching degree column and the texture map outer boundary matching degree are calculated, and the weighted outer boundary matching degree between the motion/parallax compensation block found in the reference frame is calculated. The weighted outer boundary image matching degree between the compensation block found with this co-located block through the texture map displacement vector; the reconstruction block with the smallest displacement vector compensation value is selected as the final filling block.

Step (f): Quality improvement reconstruction algorithm formula.

Use motion/disparity compensation to obtain candidate blocks in the reference frame as reconstruction blocks. If the missing block is a bidirectional reference, perform motion/disparity compensation in the front and rear reference frames, obtain candidate blocks in the two reference frames, and then combine the two The pixel values of the candidate blocks are averaged as the final reconstruction block.

Step (g): Using reference frame recombination to improve the quality of lost blocks.

According to the displacement vector of the correct receiving block around the lost block, the vector compensation is used in the current position of the lost block to obtain the reconstructed reference block in each reference frame, judge whether the reconstructed reference block position is occluded, and eliminate the unusable reference frame.

Step 1: Select occlusion judgment block.

Select 8 4 × 4 prediction unit PU blocks around each missing block as the occlusion judgment block $A_1, 1 = [1, 8]$, which are the prediction unit A_1, A_2 on the missing block, the prediction unit A_3, A_4 under the missing block, the left prediction unit A_5, A_6 for the missing block, and the right prediction unit A_7, A_8 for the missing block; Then the reference block is found by the vector compensation method, and 8 PU blocks at the same position around the reference block are selected as the occlusion judgment reference block.

Step 2: Judge whether the reference compensation block is occluded.

The reference block is found by vector compensation method, and whether the pixel value of the block increases significantly is judged by occlusion, and whether the normalized value of the pixel is greater than the judgment threshold is calculated. When one of the peripheral judgment blocks is larger than the threshold value, it is judged that the reference compensation block is occluded; if the reference compensation block is judged to be occluded, it indicates that the source frame of the reference compensation block is not suitable as the reference frame, and the reference frame caused by this part of occlusion is removed. Then, the reconstruction reference blocks obtained from each available reference frame are combined in pairs to get a new reconstruction reference block, which is used to reconstruct the damaged block; the best reconstruction block is selected as the final reconstruction block after quality improvement.

This method combines the characteristics of the new standard and improves the existing error concealment methods. It can improve the corresponding stereo video error concealment recovery technology under the new HEVC stereo video extension standard 3D-HEVC, and has a good recovery effect on the network packet loss phenomenon of stereo video in network transmission.

3 Information Security Transmission

In the information encryption part, mixed encryption is used. Because the DES algorithm is a 64-bit encryption for packet data, and a 56-bit key is used to encrypt 64-bit data blocks, there is no other effective method except for the exhaustive search method to attack DES., High security. In addition, the encryption and decryption processing of the DES algorithm can effectively apply the combination of binary forms. Therefore, the use of software and hardware can achieve high-speed encryption and decryption processing, and is suitable for large amounts of data processing. In terms of the difficulty of key generation, the DES algorithm only needs to generate 56 bits. In the key calculation, selection permutation and cyclic shift transformation are used in the key calculation; while the RSA method must select two secure large prime numbers p and q that are more than 100 digits different in decimal, and then calculate the public key and Private key. The speed is very slow and often does not meet the actual needs.

However, in terms of key management, the DES algorithm is inferior to the RSA algorithm. Because RSA is a public cryptosystem and uses a public form to distribute encryption keys, it is easy to update the encryption keys. And for different communication objects, you only need to keep your own decryption keys. The DES algorithm belongs to the symmetric cryptography system, which requires secret distribution of keys before communication. It is difficult to replace the keys, and for different communication objects, DES Different keys need to be generated and kept.

In the data transmission part, the traditional direct channel transmission is not used, but the information hiding method is used to hide the encrypted data in the image, video, text or audio signal before transmission. During the entire transfer process, only some unobtrusive ordinary files are exposed on the Internet. Even if intercepted by an attacker, it will be considered as meaningless files and discarded. Even if the secret information pool is extracted, the original plaintext can be obtained after repeated decryption, so the probability of data leakage is almost zero. The specific design plan is as follows:

Sender:

(1) The sender will randomly generate the des key K for this communication, use the key K to encrypt and compress the plaintext m to get the ciphertext cm, and use the RSA public key of the system to encrypt the key K to get the ciphertext CK, and then combine the cm and CK into the ciphertext C.
(2) When the sender encrypts the data, the ciphertext g generates a message digest by one-way hash function operation, and then encrypts the message digest with its own RSA private key to form the sender's digital signature. The sender scrambles the digital signature to get the scrambled signature CD, and combines CD and C into the ciphertext CC.
(3) The sender uses the embedding algorithm and information sharing technology to randomly hide the scrambled signature, encrypted plaintext, and encrypted symmetric key in the carrier information to obtain the hidden carrier; then, the hidden carrier is sent to the receiver.

Receiver:

(1) After the receiver receives the sender's information, the secret information in the hidden carrier is extracted through the extraction algorithm.
(2) Decompose Cc into Cd and C, and the receiver restores the scrambled signature Cd to obtain the digital signature of the sender. Use the sender's RSA public key to decrypt the digital signature to get the message digest. If it can be unlocked, it means that the plaintext is indeed sent from the sender, thus verifying the authenticity of the sender's identity.
(3) Then use a one-way hash function for C to generate a message digest. Compare the message digest and decrypt the digital signature to get the message digest. If they are the same, it means that the plaintext has not been tampered with or forged during transmission, otherwise it is false.

(4) The pseudo receiver decomposes C into Cm and Ck; and decrypts Ck with the RSA private key provided by the system to get the key K, and then decrypts Cm with the key K to get the plaintext M.

4 Experiment and Analysis

In order to verify the effectiveness of the 3D-HEVC deep video information hiding and secure transmission method, the following experiments are designed.

The experimental environment is as follows: Using the 3D-HEVC standard encoding platform HTM13.0, using the All-intra profile, encoding 100 frames, the color video encoding QP values are 25, 30, 35, and 40, and the corresponding depth video encoding QP values are 34, 39, and 40, respectively. 42 and 45, other configuration parameters are platform default values. The test sequence is 3 viewpoints and 5 viewpoints of Balloons sequence, 2 viewpoints and 4 viewpoints of Newspaper sequence, Kend. Sequence of 3 viewpoints and 5 viewpoints, Shark sequence of 1 viewpoint and 9 viewpoints, Poznan Street sequence of 3 viewpoints and 5 viewpoints, UndoDancer sequence of 1 viewpoint and 9 viewpoints, the resolution of the first 3 sequences is 1024 × 768, and the resolution of the last 3 The resolution of the sequence is 1920 × 1088.

4.1 Video Information Hiding Verification

The imperceptibility of video is also a performance index of video information hiding algorithm, that is, there is no significant decline in video quality before and after embedding information. Because the depth video is not used for viewing directly, but for drawing virtual viewpoint, the quality change of depth video after embedding information can be reflected by the quality of drawing viewpoint. Ballons sequence, newspapersequence and shark sequence are selected to illustrate.

Figure 4 shows the original video sequence (Fig. 5).

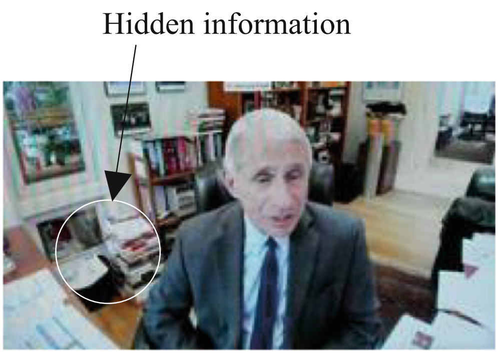


Fig. 4. Original image

(a)HEVC information hiding algorithm

(b)DCT / DST video information hiding algorithm

(c)Multi feature points

Fig. 5. Comparative analysis of different hiding methods

As can be seen from Fig. 4, after the application of the method in this paper, there is no obvious distortion in the quality of the rendering view points before and after information embedding, indicating that the imperceptibility of the video is good after the application of the method in this paper.

4.2 Video Information Security Transmission Verification

In order to further verify the application performance of the method presented in this paper, the following comparative experiments were designed: the method presented in this paper, the traditional HEVC information hiding method and the DCT/DST video information hiding method were respectively used to verify the secure transmission efficiency of video information. The results are shown in Table 1.

Table 1. Three methods of video information security transmission efficiency

Transmission times/time	HEVC information hiding method	DCT/DST video information hiding method	This paper method
1	0.62	0.72	0.98
2	0.58	0.75	0.99
3	0.55	0.83	0.97
4	0.60	0.85	0.98
5	0.57	0.86	0.98

The results of Table 1 show that the highest transmission efficiency of video information is 0.99 after using this method, which shows that this method has good transmission effect. After the application of the two traditional methods, the transmission efficiency of video information is always below 0.9. By comparison, we can see the advantages of this method.

5 Conclusion

In this study, a 3D-HEVC deep video information hiding and secure transmission method is designed. The method combining with the video image texture feature and edge information of depth video area, then according to the different areas of the depth video on the quality of the rendering virtual view, adopt different ways of modulation maximum coding unit (LCU) QP embedded secret information, on the basis of designing the concrete methods of information hiding and secure transport. According to the experimental results, this method not only has a large embedding capacity, but also can better guarantee the subjective and objective quality of video, and meets the requirements of invisibility, security and real-time of information hiding.

In the following research, we will consider to complete the information hiding processing in the process of video production, so as to effectively ensure the quality of the rendering view before and after the deep video embedding information without distortion.

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