Computer
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An Adaptive Data Hiding Method For Compressed Videos In HEVC Standard

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Received 15 May 2020; Accepted 25 December 2020

Abstract

Video information hiding has attracted increasing attention. However, few algorithms are reported to hide information in the intra prediction mode, one of the unique advantages of HEVC.As the newest video coding standard, high efficiency video coding (HEVC) has great potential as a new information hiding carrier. The data embedded in the pixels is lost when compressed with the HEVC standard. In order to solve this problem, we need to use features other than the pixel value .In this paper, an efficient data hiding method is proposed through intra prediction modes in HEVC, where the intra prediction modes is applied as the secret data carrier obtained from the N smallest prediction units. The experimental results show that the average PSNR decreased by 0.11 db, while the bit rate increased by on average 0.25%.

Keywords: Data hiding, Prediction mode, HEVC standard, Intra prediction.

1.Introduction

With the advent of computer science and information technology and expansion of computer networks and also increase in application of digital multimedia systems in recent years, data hiding in digital media has attracted the attention of researchers. Today, Internet, as a simple and quick environment for exchanging and sharing information and sending different types of digital products such as text, audio, video files and films, is well- known among different classes of international community and has caused more growth in producing these products by people and active companies in this field; thus, the necessity of using safe and secure methods to establish hidden and secret communication on the internet and computer networks has become more sensitive [1]. Data hiding algorithms can be divided into two main category spatial and transform. The first category directly performs steganography on the values of the host image pixels, while conversion domain algorithms, convert host image to conversion domain using discrete wavelet transform (DWT) and discrete cosine transform (DCT), and then insert confidential data and return them to spatial domain. The main advantage of spatial domain methods is having low time and computational complications and high run speed and also relative simplicity in their implementation. In addition, these methods can be used for different types of digital images. Against these methods, there are transform domain algorithms which show high resistance against stego analysis attacks and common processes. These methods two main weaknesses; the first one, is time consuming and computational complexity for the reason of transferring images to transform domain and returning them to spatial domain using reverse method and another weakness is the fact that they can be used just for a special category of images like the ones with JPEG[2].

One of the most important functions of data hiding is in videos. Since videos are compressed to store data, these hidden data can be added to the video before or after compression. If the

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hidden data be embedded in the video before compression, they may be lost. Another method of embedding data is during compression that which do not the problem of previous method. The most recent standards of video compression, is high efficiency video coding (HEVC) which has been introduced in 2013 [3]. For this reason, studying methods for data hiding in compressed videos with HEVC standard are considered. The proposed method use the features of HEVC standard to hide data in compressed videos in HEVC Standard. Various works and studies been done in the field of data hiding in HEVC Standard.

Long et al. [4] used the remaining coefficients after prediction in HEVC standard to hide data. In HEVC standard along with motion vectors, motion compensation matrix which includes differences of prediction image and original one is stored. They use non-zero coefficients of motion compensation matrix (remaining coefficients) to store data in them. To increase security, first the video and hidden messages are encoded and then hidden data are embedded in non-zero coefficients of motion compensation matrix.

Sowati et al. [5] used transform blocks in HEVC standard to hide data. Transform block includes results of converting DCT on motion compensation matrix. The size of transform blocks can be varied from 4×4 to 32×32. They used less significant bits of transform block-coefficients to hide data. Gooei and Zive [6] used transform blocks in HEVC standard. They considered the size of transform blocks as 8×8 and coefficients which are close to intermediate frequency as hidden data carriers. Chang et al. [7] presented a method for hiding data in frames which are coded internally in HEVC standard. In this method they implemented error distribution in neighbouring blocks. In their method, they analysed DCT/Discrete Sine Transform (DST) signal features to find signals which do not any role in error distribution to adjacent blocks or frames. The reported result show improvement in the embedded bit capacity compared with the other methods. Vang et al. [8] used intra prediction modes for data hiding. They selected the best prediction modes of 4×4 blocks and calculate the difference of angles between two consecutive block modes. Then they modified prediction modes based on hidden data series. Their method is useful only when the videos are coded in the form of intra frame. The authors in [9] used the absolute moment block truncation coding (AMBTC) compressed images to hide data according to the histogram modification. They indicated that their proposed method a high embedding capacity compared to other methods. A reversible data hiding for encrypted halftone image based on the Haming code is proposed by the authors in [10]. The first, image is encrypted by the encryption key, and next, the data embedder hides the secret data in the encrypted image through the data hiding key. The reported result show that embedding payload decreases along with low image quality. In [11], a reversible data hiding for H.264/AVC through motion vector according to 2-D histogram modification is proposed. They used the motion vector to compose an embedding pair and next, the embedding pair is categorized into 17 sets, and then the data are embedded into motion vectors through modifying the embedding pair based on the set to which the embedding pair belongs to. An efficient data hiding algorithm for HEVC videos is proposed by Saberi et al [12], through intra prediction modes integrated with HEVC, where the intra prediction modes of HEVC encoded videos are used as a secret data carrier obtained from the N smallest prediction units. Their results indicated that the embedding capacity increases, while achieving the best performance among the compared methods.

Since HEVC Standard uses DCT transform to compress videos, all the available methods used transform blocks to hide data, while the proposed method uses prediction modes to carry data in embedding process. To embed L bit of hidden data, only one of the prediction modes will increase or decrease. Additionally, one key is used to embed and extract hidden message and embedding will be done using N/2 of smallest prediction blocks as host. Using features of HEVC content and capability of embedding data in compression process of HEVC video currents, probability of security attacks will be minimized. Compared to other methods, the proposed method is able to create more embedding capacity with security after embedding data in HEVC videos.
The rest of paper is organized as follows: in section 2, the background including a review on HEVC standard and intra frame and inter frame is explained to the extent which is necessary for

understanding the other parts in the paper. The proposed method which includes the carrier vector selecting and embedding and extracting data are presented in section 3. In section 4 measurement parameters and results analysis and also comparing the proposed method with other works are presented. Finally, conclusion will be given in section 6.

2.Background

For a better understanding of suggested method, there is a short review on HEVC compression standard and different predictions used in it. More details are presented in Ref. [13].

2.1 HEVC Standard

HEVC is the most recent video compression standard. In 2010, Joint collaborative team on video coding (JCT-VC) started HEVC project during a public announcement for standardizing modern methods of video compression. Based on the modifications which been done in various meetings on received proposals, in 2013 the last draft and an experimental model named HM were published. With applying the best and most efficient available algorithms, the amount of video compression were about 50% more than previous standards like H.264/AVC which was considered as a great step [14]. Fig. 1 shows encoding diagram and compression process of frames in HEVC video standard. The encoder, predicts one block and subtract it from the main block to gain the remaining block. Then quantization will be done on remaining block. Inverse quantization and conversion will be applied on the result for the remaining matrix to be restored. Prediction block will be added to the restored remaining matrix. HEVC standard uses two types of intra frame and inter frame one for compression which will be explained in details.

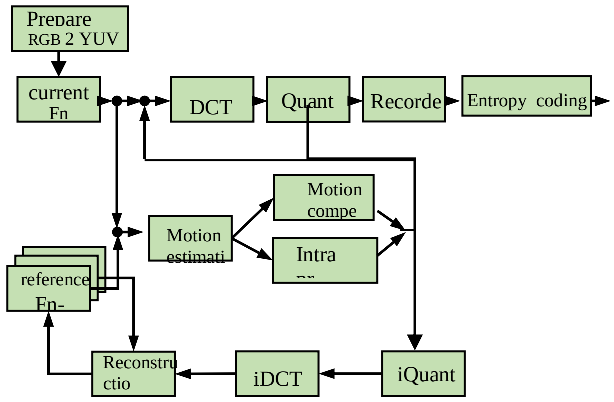


Fig.1.: Encoding diagram in HEVC video standard [14].

In HEVC Standard, each image is divided into blocks of 64×64 pixels called coding tree unit (CTU). Then these CTUs will be divided into coding unit (CU) as quad-tree where CTU is known as the root of this tree and each encoding unit includes one luma and two chroma blocks and its size can be $2^n \times 2^n$ which n is an integer between 3 to 6. Each encoding block, determines a part of image which the same prediction mode. Fig. 2 shows division of one CTU to encoding units with the size of 64×64 to 8×8. Numbers in each block show the order of each block being encoded.

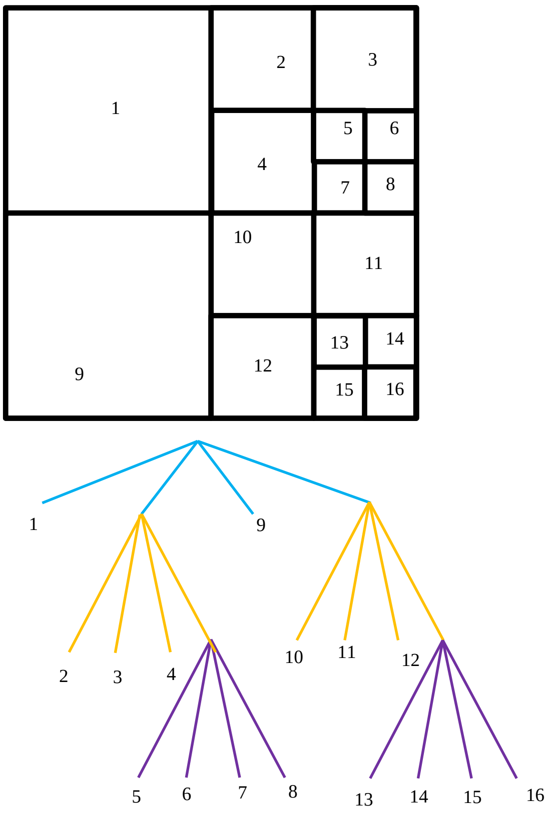


Fig.2. An example of division of one CTU to encoding blocks.

Each encoding block can include one or more prediction unit (PU). In each PU, the same prediction process will be done. In intra frame prediction minimum size of encoding unit is 8×8 which can be broken into units with the 4×4 size, in other words in intra frame prediction the size of prediction block can be from 64×64 to 4×4. In inter frame prediction the size of prediction block can be a coefficient of encoding block which in this case encoding block can be broken into 8 different modes. Different sizes are shown in Fig.3. In addition, Fig.4 shows an example of division of one encoding unit in intra frame prediction mode with 64×64 to various prediction units. Each prediction block includes one or more transform unit. Transform unit is the one which is used for Discrete Cosine Transform (DCT). Maximum size of conversion block is 32×32 and minimum size is 4×4.

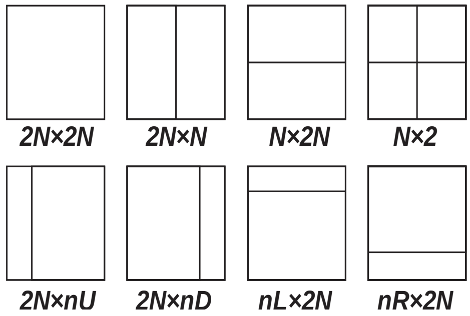


Fig. 3. Eight modes for dividing CU to PUs [15].

2.2 Intra Frame Prediction

HEVC standard uses intra frame prediction for removing spatial redundancy. In this prediction, adjacent block pixels in the same frame which was previously encoded are used for prediction. In this type of prediction for getting the best prediction mode, 35 different modes will be used are shown in Fig. 4.

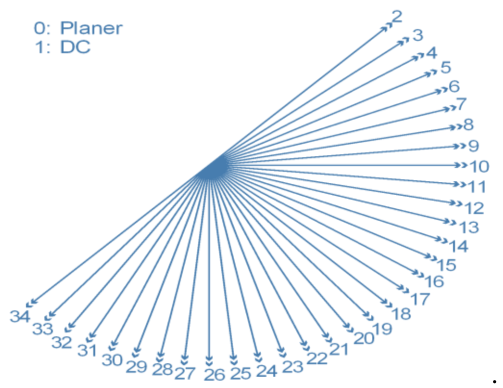


Fig 4. different intra prediction modes, used in HEVC [15].

These 35 directions are evaluated on blocks with different sizes of 64×64 to 4×4 and block with proper size and optimized mode will be selected. To select the best mode and block size, rate distortion optimization process is used as: [16]

$$J = SSD + \lambda R \qquad (1)$$

where, *SDD* in squared sum of difference between pixels of main encoding unit and the prediction unit. λ is Lagrange coefficient and R is the number of real bits which are needed for encoding blocks.

3. Proposed Method

In the intra prediction process, each PU has a mode, to predict the current PU. In the proposed method, we use these prediction modes as hidden data carriers. In order to increase security, a number of PUs been selected and their prediction modes will be used as data carriers. The details of the proposed method will be discussed in following section.

3.1 Ccarrier Vector

After video compression for selecting a PU to embed data can be used the following three conditions:

A) If the right blocks has prediction mode between 26-34 or the top-right block has prediction mode 10-34 (Fig.6). The pixel values in the right column of the selected block will not be used in prediction, so the data can be embedded in that block.

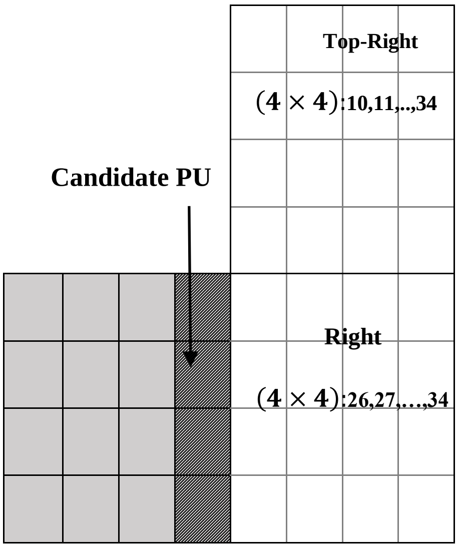


Fig.6. The current block meets condition 1. In this case, pixels in candidate PU not used to predict pixels in right and top-right Pus

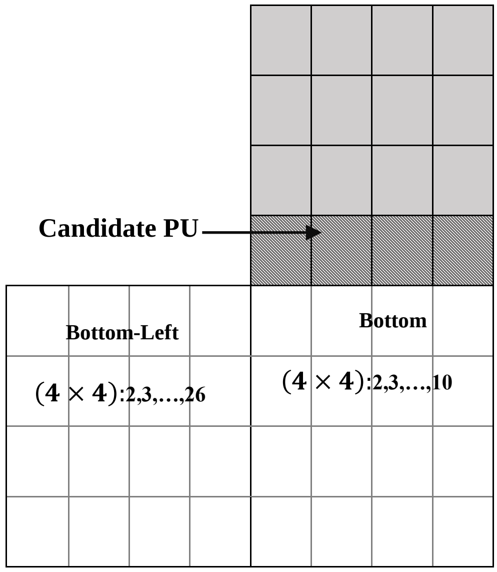


Fig.7. The current block meets condition2, In this case, pixels in candidate PU not used to predict pixels in bottom and bottom-left PUs

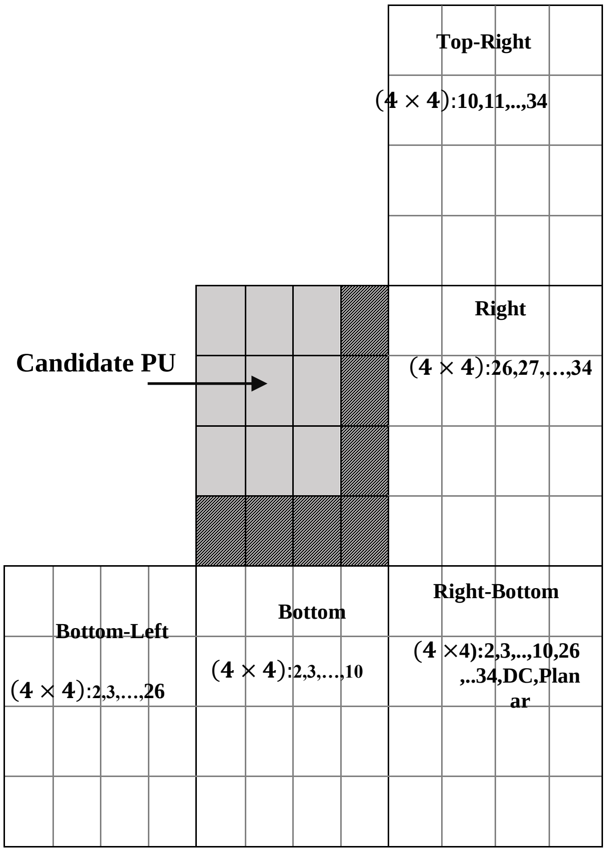


Fig.8. The current block meets condition3.

B) If the bottom of the selected PU has a prediction mode of 2-10 or the bottom-left block has the prediction mode of 2-26, the lowest row of the selection block is not used in the prediction (Fig.7).

Algorithm 1: pseudo-code of proposed data embedding.

BEGIN

FOR EACH CTU in the I-frame **DO**

$\boldsymbol{IF}$ Bottom − Left mod e of PU $\in \{2,3,\ldots.26\}$ $AND\ \ Bottom\ mod\ e\ \in$ $\{2,3,\ldots 10\}$ OR Top − Right mod e $\in \{10,11,\ldots,34\}$AND Right mod e $\in \{26,27,\ldots,34\}$ $OR\ Right - Bottom\ mod\ e \in \{2,3,\ldots,10,26,27,\ldots,34, Dc, Planar\}\boldsymbol{THEN}$

$list.append(m_i)$

n ← ⌊length(list/3)⌋

$k \leftarrow log_2^{n+1}$

FOR t=1 to n **DO**

S← m[t: t + k]

FOR i=t to t+3 **DO**

$p(m_i) \leftarrow \mathrm{LSB}(m_i)$

$\boldsymbol{\alpha} \leftarrow \mathbf{S} \oplus \left(\bigoplus_{\boldsymbol{j}=\mathbf{1}}^{\boldsymbol{k}} (\boldsymbol{p}(\boldsymbol{m_i}).\boldsymbol{j}) \right)$

IF (α = 0) **THEN** go to next CTU

$\boldsymbol{ELSE}$ $p'(m'_i) = 1 - p(m_i)$

Obtain odd mode(m'_α)

Obtain SATD(m_α)

$G \leftarrow odd\ mode \cap\ SATD$

f ←Min RD(G)

change $m_\alpha\ to\ \ m_f$

END IF

END IF

END FOR

END FOR

END FOR

END

If a prediction block meets condition1, the pixel values of its samples on the lowest row will not be used in the intra-frame prediction of its bottom-left block and bottom block, so we can do the data embedded in this block.

C) If the bottom, bottom-left, right and top-right blocks of the selected PU contains the modes listed in condition 1 and 2, the pixels in the lower row and right column of the selected block is not used in prediction then, the data can be embedded in that block (Fig.8).

3.2 Data Embedding

The proposed method uses prediction mode as a hidden data carrier. Before embedding, the data must be converted into binary string. First, the number of PUs, that a prediction mode that includes the condition 1 and 2 and 3 are selected. Next, the k-bit of the message are selected where k is obtained as:

$$K = log_2^{n+1} \quad (2)$$

where, *n* is the prediction mode of block that must be modified can be obtained as [15]:

$$\alpha = S \oplus \left(\bigoplus_{j=1}^{k} (p(m_i).j) \right) \quad (3)$$

where , $p(m_i)$ is the LSB of m_i and $\oplus$ is the XOR operator. if α =0, none of the prediction mods need to be modified and the process of data embedding in that CTU ends; otherwise,m_α needs to be changed to m'_α. Algorithm 1 shows the pseudo-code of the proposed method.

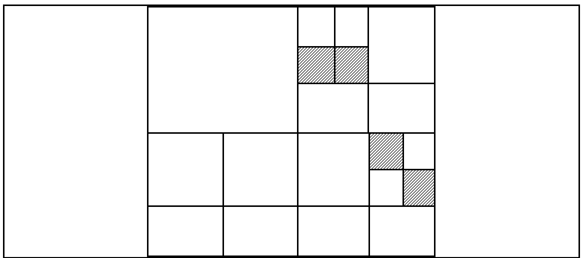
Since the prediction mode are applied for embedding data hiding, all frames are coded as intra coding (line 2). The selection of suitable prediction blocks is determined to carry out the hidden data (line 2).Prediction modes with optimal conditions are stored in the list (lines 5-6). A binary string with k length is extracted from secret data and is placed in the s variable (lines 6-8). The LSB (m_i) is computed and placed in the p (m_i) (lines 9-10). The α - value is then calculated from Eq. (3) (line 11). If α is equal to zero, the data hiding is ended and no intra modes should be modified (line 12), otherwise the modified modes should meets $p'(m'_i) = 1 - p(m_i)$.

The prediction mode are divided into two groups based on their LSB:

Odd modes and even modes. Group odd modes include the modes which the opposite LSB from m'_α and Group even mode include the modes which the same LSB from m'_α. Sum of absolute transformed differences (SATD). Also, the prediction modes can be divide to two group's base on SATD consists of SATD and NSATD (none SATD). SATD include eight modes obtained from the RMD phase and the NSATD contain modes other than SATD. The modes in both group odd mode and SATD into the G variable and the RD modes calculated and the mode that has the lowest cost is placed in the f variable. Then m_α is changed to m_f (Lines 13 - 24) .An example of the CTUs encoded by the HEVC standard is shown in Fig .10.

In this example, the hidden data to be embedded is "10". The shaded prediction blocks are selected as the carrier. Let us assume m1 =4, m2 =10, m3 =13, thus P (m1) =0, P (m2) = 0, P (m3) = 1; the two bits secret information S= 10. Then, according to (5), α = 10 ⊕ (0×1 ⊕ 0×2 ⊕1×3) =10⊕11=01. Therefore,m1 should to be modified to m'_1 which satisfying P(m'_1) =1.So,Group odd modes={1,3,5, ..., 33}.

Assume that group SATD={1,2,3,8,10,11,13,15} ,then G={1,3,11,13,15}. Next , the RD cost of modes 1, 3, 11,13,15 are calculated respectively. If mode 1 has the minimum RD cost in all modes, m'_α =1. This process is repeated for all carrier CTUs to embed all the hidden data.



m="10"
$m_1 = 4, m_2 = 10 , m_3 = 13$
S=10
LSB(m_1) = 0 , LSB(m_2) = 0 , LSB(m_3) = 1
$\alpha = 10 \oplus$ (1×0 ⊕ 2×0 ⊕ 3×1)=1
Odd modes=
{1,3,5,7,9,11,13,15,17,19,21 ,23,25,27,29,31,33}
SATD={1,2,3,8,10,11,13,15}
G={1,3,11,13,15}
RD=3
m1=3

Fig. 9. An example of the proposed data embedding.

3.3 Data Extracting

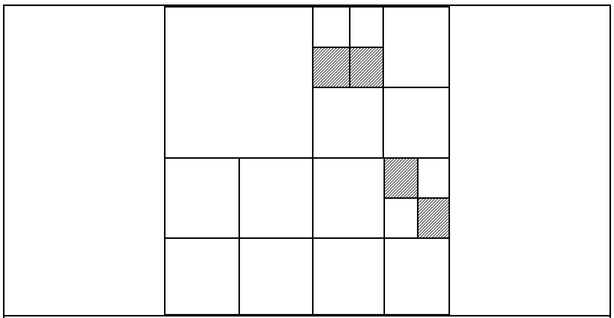
The extraction of embedded data is calculated as:

$$S = b(m_i) \qquad (4)$$

where, s is hidden data embedded in the current PU and b(m_i) can be obtained as:

$$b(m_i) = \bigoplus_{j=1}^{n} (m_{ij}).j \qquad (5)$$

After extraction of all the data embedded in the PUs. The whole embedded data by joining the strings can be restored.



$m_1 = 3, m_2 = 10, m_3 = 13$
LSB(m_1) = 1, LSB(m_2) = 0, LSB(m_3) = 1

S=(1×1 ⊕ 0×2 ⊕ 3×1)=01 ⊕ 11=10

Fig. 10. An example of the proposed data extracting

4.Simulation Results

The proposed method is implemented in HEVC reference software version HM 16.20 [17]. In this paper, 10 well-known standard video sequences with different textures and resolutions are applied for simulation, where only the first 100 frames a re applied in the simulations .These sequences ar e encoded as all - intra.

4.1. Performance Metrics

In this paper, the visual quality, bit-rate variation, embedding capacity metrics are analyzed to evaluate the performance of the proposed method.

4.2.Viual Quality

The visual evaluations are applied to measure the visual quality of embedding videos. The peak signal to noise ratio (*PSNR*) and structural similarity index for measuring (*SSIM*) are applied as visual evaluations .The PSNR is the most widely applied metric for measuring the distortion between the cover image and the embedded image. The PSNR of an image is expressed as [18]:

$$PSNR = 10\, log_2 \left(\frac{255^2}{MSE}\right) \qquad (6)$$

where, the mean square error (*MSE*) of an M×N image is computed as :

$$MSE = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} (S[i][j] - C[i][j])^2 \qquad (7)$$

where, *S* is the cover image and C is the embedded image. The MSSIM metric is applied to measure the visual quality of embedding videos. The MSSIM of a video with M×N resolution is calculated as [19]:

$$MSSIM(S,C) = \frac{1}{M \times N} \sum_{K=1}^{N} \frac{(2\mu_s\mu_c + C_1)(2\delta_{s,c} + C_2)}{(\mu_s^2 + \mu_c^2 + C_1)(\delta_s^2 + \delta_c^2 + C_2)} \qquad (8)$$

where , μi is the average of image i, and $\delta i,j$ is the covariance of images s and c.c1 and c2 are constant.

Embedded rate

This parameter indicates the average number of bits embedded in each frame that is calculated as:

$$\boldsymbol{R = \frac{r}{N}} \qquad (9)$$

where, r is the total number of embedding bits and N is the total number of frames .

Bit-rate:

This parameter indicates the increase or decrease rate of the video bit rate in the HEVC standard that is calculated as:

$$\mathbf{BRI} = \frac{\mathbf{BR} - \mathbf{BR'}}{\mathbf{BR}} \times \mathbf{100} \qquad (10)$$

where, *BR* is the video bit-rate without embedding and *BR*' is the video bit-rate after embedding.

4.3.Performance Results And Analysis

The data embedded capacity is shown for each frame in Fig. 11. As shown in Fig. 10, the maximum embedded rate is 1443 per frame. Since, different videos different resolution and texture, the count of PUs is different in each frame, so the embedding capacity is different in each frame.

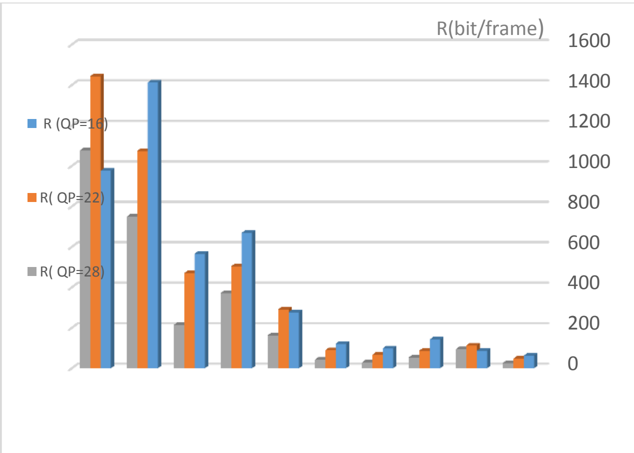
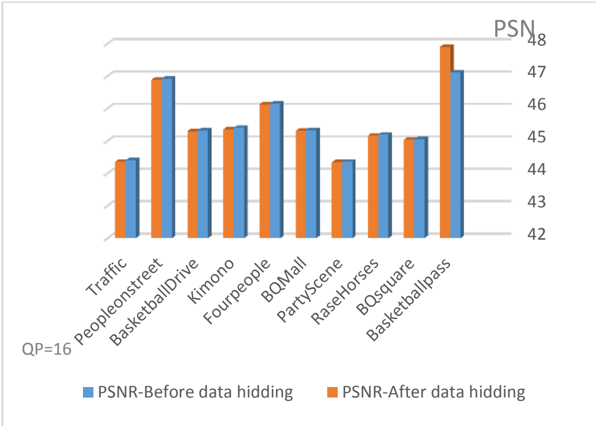


Fig. 11.The embedded capacity of the proposed method.

Fig. 12 (a) shows the PSNR and (b) MSSIM of the embedded image and the cover image after extracting the data hiding with the proposed method. These parameters are measured for different values of the QP.



(a)

(b)

Fig.12. comparison of the quality and criteria of the similarity of the videos before and after the embedding data in the proposed method.

The bit rates change for different videos with different QP is shown in Fig.13. Table 1 shows the comparison between the proposed method and other recent works for compressed videos in the HEVC standard. As observed in Table 1, the proposed method is proper for videos that compressed by HEVC standard.

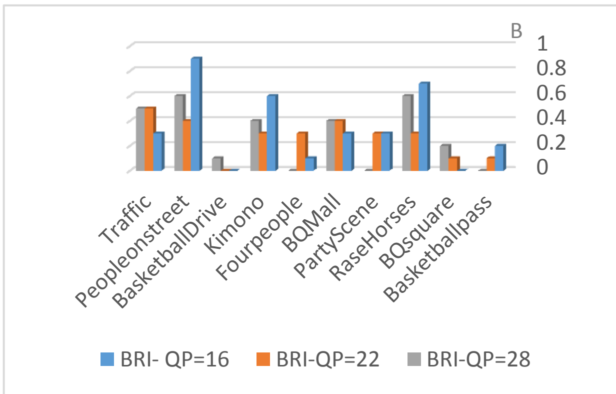


Fig.13.The ratio of the increase bitrate of the different videos w ith different QPs

Table 1
Comparison of the proposed method with related works.

Method	prediction	BRI	dPSNR	R
Liu et al. [18]	Intra	0.98	0.22	838
Yang et al. [19]	Intra	1/95	0.12	779
Proposed method	Intra	2.07	0.19	1740

5. Conclusion

In this paper, a new method is presented to hide data in videos encoded by the HEVC standard. In the proposed method, the prediction modes of intra prediction blocks used. The results show that the proposed method has good embedded capacity while the bit rate is not increased and even the bit rate may be reduced. Comparison with the recent works show that the proposed method has the least effect on compression performance of HEVC standard.

References

[1] Bo, P. and Y. Jie (2018). "A Reversible Information Hiding Method Based on HEVC." IFAC-PapersOnLine **51**(17): 238-243.

[2] Hou, D., Wang, H., Zhang, W., & Yu, N. (2018). Reversible data hiding in JPEG image based on DCT frequency and block selection. Signal Processing, 148, 41-47.

[3] Liu, X., Ding, W., Shi, Y., & Yin, B. (2018). Content adaptive interpolation filters based on HEVC framework. Journal of Visual Communication and Image Representation, 56, 131-38.

[4] Long, M., Peng, F., & Li, H.-y. (2018). Separable reversible data hiding and encryption for HEVC video. Journal of Real-Time Image Processing, 14(1), 171-182 .

[5] Swati, S., Hayat, K., & Shahid, Z. (2014). A watermarking scheme for high efficiency video coding (HEVC). PloS one, 9(8), e105613.

[6] Gui, F., & Xue, H. (2017). *A Reversible Data Hiding Scheme for HEVC.* Paper presented at the 2017 10th International Symposium on Computational Intelligence and Design (ISCID).

[7] Chang, P.-C., Chung, K.-L., Chen, J.-J., Lin, C.-H., & Lin, T.-J. (2014). A DCT/DST-based error propagation-free data hiding algorithm for HEVC intra-coded frames. Journal of Visual Communication and Image Representation, 25(2), 239-253

[8] J. Wang, R. Wang, W .Li, D. Xu, and M. Huang, "A high-capacity information hiding algorithm for HEVC based on intra prediction mode," J. Comput. Inform. Syst, vol. 10, pp. 8933-8943, 2014.

[9] Liu, Y., Liu, S., Zhao, H., & Liu, S. (2019). A new data hiding method for H. 265/HEVC video streams without intra-frame distortion drift. *Multimedia Tools and Applications, 78*(6), 6459-6486.

[10] Kim, C., Shin, D., Leng, L., & Yang, C. N. (2018). Lossless data hiding for absolute moment block truncation coding using histogram modification. *Journal of Real-Time Image Processing,* 14(1), 101-114.

[11] Kim, C., Shin, D., Leng, L., & Yang, C. N. (2018). Separable reversible data hiding in encrypted halftone image. *Displays,* 55, 71-79.

[12] Li, D., Zhang, Y., Li, X., Niu, K., Yang, X., & Sun, Y. (2019). Two-dimensional histogram modification based reversible data hiding using motion vector for H. 264. Multimedia Tools and Applications, 78(7), 8167-8181.

[13] Saberi, Y., Ramezanpour, M., & Khorsand, R. (2020). An efficient data hiding method using the intra prediction modes in HEVC. Multimedia Tools and Applications, 79(43), 33279-33302.

[14] Cheddad, A., Condell, J., Curran, K., & Mc Kevitt, P. (2010). Digital image steganography: Survey and analysis of current methods. Signal Processing, 90(3), 727-752.

[15] Wang, J., Jia, X., Kang, X., & Shi, Y.-Q. (2019). A cover selection HEVC video steganography based on intra prediction mode. IEEE Access, 7, 119393-119402 .

[16] Dong, Y., Sun, T., & Jiang, X. (2018). A High Capacity HEVC Steganographic Algorithm Using Intra Prediction Modes in Multi-sized Prediction Blocks. Paper presented at the International Workshop on Digital Watermarking.

[17] https://hevc.hhi.fraunhofer.de/trac/hevc/browser#tags.

[18] S. Sharda and S. Budhiraja, "Image steganography: A review," International Journal of Emerging Technology and Advanced Engineering (IJETAE), vol. 3, pp. 707-710, 2013.

[19] Z. Wang, A. C. Bovik, H. R. Sheikh, and E. P. Simoncelli, "Image quality assessment: from error visibility to structural similarity," IEEE transactions on image processing, vol. 13, pp. 600, 2018.