Alexandria Engineering Journal (2016) **xxx**, xxx–xxx

HOSTED BY
ELSEVIER

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

ORIGINAL ARTICLE

Improved entropy encoding for high efficient video coding standard

B.S. Sunil Kumar [a,*], **A.S. Manjunath** [b], **S. Christopher** [c]

[a] *GM Institute of Technology, India*
[b] *Siddaganga Institute of Technology, India*
[c] *Department of Defence R&D & DG, DRDO, GoI, India*

Received 6 July 2016; revised 2 September 2016; accepted 4 September 2016

KEYWORDS

Entropy;
Encoding;
HEVC;
PSNR;
Compression

Abstract The High Efficiency Video Coding (HEVC) has better coding efficiency, but the encoding performance has to be improved to meet the growing multimedia applications. This paper improves the standard entropy encoding by introducing the optimized weighing parameters, so that higher rate of compression can be accomplished over the standard entropy encoding. The optimization is performed using the recently introduced firefly algorithm. The experimentation is carried out using eight benchmark video sequences and the PSNR for varying rate of data transmission is investigated. Comparative analysis based on the performance statistics is made with the standard entropy encoding. From the obtained results, it is clear that the originality of the decoded video sequence is preserved far better than the proposed method, though the compression rate is increased.

1. Introduction

Efficient transmission of video through the Internet is of great concern in the recent years because of the wide growth of the Internet and the multimedia applications. This necessitates advanced video coding with limited bandwidth usage. Hence, the Joint Collaborative team on video coding enacted the High Efficiency Video Coding (HEVC) standard [8] for supporting high bit rates, more colour formats, spatial and fidelity scalability and multi-view video coding. The HEVC standard is the advanced form of H.264/MPEG4 part 10-Advanced Video Coding (AVC) standard [9,18]. It consists of multiple coding tools such as prediction unit, coding unit and transform unit in quadtree coding block partitioning tool [17]. The quadtree is a phenomenon used for subdividing the picture into many blocks, so as to enable coding and prediction [11]. In video coding, intra coding provides good quality videos [19]. As a result, the HEVC outperforms the conventional video coding standards. Yet, it has the drawback of computational complexity and storage problems, while encoding [10]. A lot of research works have been done in relation to the HEVC. From the literature review, it is found that few works are contributed towards the area of fast mode decision making in HEVC. In 2016, Honrubia et al. [2] have introduced a novel algorithm, named Adaptive Fast Quadtree Level Decision (AFQLD) algorithm, for making faster decisions on the coding unit split up in HEVC. Earlier, the faster decision making problem has

* Corresponding author.
E-mail address: sunilkumar.bs127@gmail.com (B.S. Sunil Kumar).
Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2016.09.003
1110-0168

been addressed in 2015 by Hu and Yang [5] and they have proposed a fast Intra Mode Decision (OIMD) algorithm for minimizing the computational complexity in HEVC. In the same year, Yeh et al. [6] have proposed a novel intra prediction model, which is based on two neighbouring predictor syntheses.

The overview of HEVC, particularly focussing on the recent developments in the 3D and multi view video, has been addressed in 2016 by Tech et al. [1]. They have studied the overview and various features of Multi View (MV) video and depth-based 3D video formats in High Efficiency Video Coding (HEVC). Increasing the coding efficiency by improving the bit allocation has been experimentally studied in 2014 by Wang et al. [7]. They have developed a gradient-based R-lambda (GRL) for controlling the intra frame rate in HEVC to minimize the BER and enhance the video quality. The algorithm has the capability to measure the frame-content complexity and it is an advanced method for improving the performance of the conventional R-lambda. Additionally, they have also developed a coding tree unit level bit allocation method. Several works were focussed on the transform coding techniques in HEVC. In 2013, Nguyen et al. [4] have studied various HEVC techniques that are used for transforming the codes and to perform entropy coding. They have used the quadtree-based partitioning, dubbed as residual quadtree, as one of the new transform coding techniques that support in increasing the size of the transform blocks and dividing the residual blocks into multiple blocks. In 2012, Sole et al. [3] have worked on transform coefficient coding in HEVC that includes the scanning patterns and coding methods, sign data, coefficient levels and significant map.

Our paper focuses on improving the entropy encoding of HEVC to accomplish better encoding performance [20]. The paper is organized into the following sections. In Section 2, the drawbacks in the existing works are pointed and the contributions of our paper are presented. Section 3 is about the HEVC and the encoding procedure. Section 4 explains about the construction of the improved entropy coding, which includes the weighted entropy and the optimization procedure. Section 5 discusses the results and Section 6 concludes the paper.

2. Problem definition and our proposed solution

2.1. Preliminaries

The HEVC has added features such as, parallel processing architectures and high video resolution, which are not present in H.264/MPEG-4AVC. Moreover, the syntax and the bit stream structure are completely standardized in HEVC and it have some features such as coding efficiency, data loss resilience, ease of transport system integration and implementation with parallel processing architecture. The quarter sample precision is applied for yielding the motion vectors in HEVC, but the half sample positions are used in H.264/MPEG-4AVC. For the interpolation of fractional sample positions, 7 or 8 tap filtering and 6 tap filtering are used in HEVC and H.264/MPEG-4AVC respectively. The HEVCs association syntax is very simple and it supports large TB sizes and prediction directions than the H.264/MPEG-4AVC that occupies 16×16 size of luma PB in plane prediction, which is opposite to the HEVCs' assistance to each block. Only one entropy coding and three probable modes in luma intrapicture prediction mode coding are supported by HEVC, which are quite contrast to the H.264/MPEG-4AVC that supports two entropy coding methods and one mode in luma intrapicture prediction mode coding. Also, the descaling operation feature in the dequantization step is a needed one for H.264/MPEG-4AVC, but not for HEVC.

2.2. Problem definition

The key motive of the digital video coding standard is the optimization of coding efficiency. The ability of a coding standard to reduce the bit rate that represents a video content with desired video quality level is known as the coding efficiency. It can also be defined as the ability of the coding standard to increase the quality of the video, with limited bit rate. The first version of the High Efficiency Video HEVC standard [12], approved as ITU-T H.265 and ISO/IEC 23008-2, has achieved the first motive and then they concentrated on the key extensions of its abilities to suit for the needs of a wide number of applications. The old version of the HEVC standard had a better scope. But, it has not given any importance to the key features for designing the core elements In the development of the new HEVC standard encoding scheme, the extensions that are considered, while preparing this paper (pointing to the present status that the Vienna meetings of July/August 2013 holds), can be divided into three areas: the range extensions, the scalability extensions and the 3D video extensions. In the range extension, the bit depth ranges and the colour sampling formats are enlarged. It also focuses on the performance of the high-quality coding, the screen-content coding and the lossless coding. The scalability extensions allow the usage of the embedded bit stream subsets and they are represented in the form of reduced-bit rate The 3D video extensions increase both the stereoscopic and the multi-view representations, in addition to the capability of the novel 3D that involves the use of depth maps and view-synthesis methodologies [13].

In the literature [13], it has been stated that both the quality and the loss of information have to be studied for the HEVC standard coding scheme. Improving the compression efficiency of the existing HEVC standard seems to be a great challenge. In [14] and [15], the architectural coding schemes have been discussed and they mainly focus on the improvement of the computational efficiency of the encoder and not on the loss of information loss and the preservation of the decoded videos quality. Similarly, the algorithm level encoding schemes in [16] and [5] have also focussed on reducing the computational complexity of the encoding scheme. The coefficient coding has been addressed in [3] and it has mainly focussed on the protection of encoding. But, those methods won't suit for all the video formats. So, for applying such types of encoding schemes, the adaptive coefficient selection schemes are needed. In [4], the entropy coding has been studied with the main concentration on the computational efficiency and the precision. Other than that, the bottlenecks for improving the performance of the HEVC also have a lot of drawbacks that persist still in the inter-prediction and intra-prediction methods of HEVC. The drawbacks are as follows:

- Decrease in the coding efficiency, due to misalignment.
- High computational time.

- If not aligned, the effectiveness of coding tools with a dependency between the texture and the depth component will decrease.
- The reference pixels in the up-right block are not considered for similarity.
- The performance improvement is not significant for very complex sequences.

2.3. Our contributions

Our key contribution relies on proposing an improved version of the standard entropy encoding method for HEVC. Since the standard entropy encoding lacks competing performance, we improve it by introducing the weightage factors for the rate of coding bits. The weighing range depends upon the resolution and the perceptivity of the video contents. Hence, a recently introduced optimization algorithm, called as the firefly algorithm, is exploited.

3. HEVC and its encoding procedure

3.1. Architecture

The high level architecture of HEVC is presented in Fig. 1. The inter picture or/and the intra picture prediction used in HEVC include the transform coding of the video frames into blocks and it is completely based on the standards of video compression. In order to detect the spatial relevance among the frames, the intra-prediction step was used in the video's first sequence and the inter-picture prediction depended on the relevance within the frames to deduce the motion vector and a reference frame. The deduced motion vector was utilized for predicting each frame's block sample using the mode decision data and motion compensation. From the obtained results of the prediction process and the original block, the residual signal was formed and it underwent the linear spatial transform later. Moreover, the resultant transformation coefficients undertook the process of scaling, quantization and entropy coding. The HEVC encoder itself has a decoder, where the residual signal was retrieved by processes such as, inversing, scaling and transformation. The residual signals come under the prediction outcome and they were placed in the loop filter, where the artifacts are being removed. The copy of the decoder output was saved in the decoded picture buffer and this was handed down to predict the next frames. The HEVC's hybrid video coding context includes, Coding blocks and units, Coding Tree Units and Coding Tree Blocks (CTU and CTB), Transform Units and Transform Blocks (TU and TB), Prediction Units and Prediction Blocks (PU and PB), Motion Vector (MV) signalling, Motion Compensation (MC), intra picture prediction, quantization, entropy encoding, Sample Adaptive Offset (SAO) and in-loop de blocking filtering. The CTU was compared with that of the macro block of the traditional coding standards, yet the size of the new standard CTU remained large. The CTB includes associated chroma CTB, luma CTB and syntax elements. Among the three, the size of luma CTB was big and so, they were divided into minor blocks using the quadtree like signalling [12] and the tree structure. In CTU, the quadtree syntax defined the size and position of the luma as well as the chroma CBs. The CTU formed the base of the quadtree and so, the maximum size of the luma CB was the size of the luma CTB. With one luma CB and two chroma CBs, the CU can be built with the respective quad tree syntax. However, a CTB comprises one CU or multiple CUs that can be sectioned to PUs and TUs, but both of them have root at the level of CU. The CBs can be split and it can be predicted by PBs.

There exists a strong similarity between the luma CB residual and the luma transfer block and so, it can be joined to form the smaller luma TBs. The process of motion vector signalling in HEVC includes the Advanced MV Prediction (AMVP), having the special feature of inheriting from PBs related to the spatial and temporal neighbourhood. The quarter sample precision with 7 or 8 tap filterings is used for motion vector signalling in HEVC, when the motion compensation process occurs. However, in H.264/MPEG-4AVC, the half sample positions with 6 tap filtering are used during the motion vector signalling. Other than that, in HEVC, multiple pictures can be used for individual PB-one or two motion vectors can be transmitted for uni or bi predictive coding. For predictive signalling, the scaling and the offset operation were utilized. In H.264/MPEG-4AVC, 8 directional modes were considered during intrapicture prediction. Yet, HEVC accepts 33 directional modes and the decoded boundary samples in the nearby blocks are the reference data.

The Context Adaptive Binary Arithmetic Coding (CABAC) is modified in HEVC for maximizing the compression performance as well as the throughput speed and minimizing the context memory requirements. For both HEVC and H.264/MPEG-4AVC, the deblocking filter in the interpicture prediction loop is same. When the filtering process and the decision making process were ongoing, congestion occured in the structural framework. In addition to the deblocking filter in the interprediction loop, a nonlinear amplitude mapping was also used. With the aid of a novel lookup table, the signal amplitudes were rebuilt and evaluated by the histogram analysis, closer to the encoder side.

3.2. Encoding procedure

CABAC, which is the only entropy coding method of HEVC in modified form, has special features such as adaptive coefficient scanning, context modelling and coefficient coding. The context modelling was used for maximizing the efficiency of the CABAC and the indices for the context modelling were obtained from splitting the depth of the transform tree. These indices include many syntax elements such as split_coding, unit_flag, cbf_luma, skip_flag, cbf_cr, cbf_cb, and split_transform flag. The split_transform_flag indicated the splitting of TB and spli_coding_unit_flag was used for indicating further splitting of CB and it was coded depending upon the spatially neighbouring information. The skip_flag points out that the CB coded in the form of inter picture was predictively skipped and the coding for cbf_cb, cbf_cr and cbf_luma was based on the splitting depth of the transform tree. To increase the throughput, the data were minimized with the bypass mode of CABAC in HEVC.

In order to scan, various kinds of coefficient scanning methods such as horizontal, diagonal upright and vertical scans were applied and depending upon the directionality of the intra picture predicted regions, the scanning orders were selected. The horizontal scan was used, when the prediction

Please cite this article in press as: B.S. Sunil Kumar et al., Improved entropy encoding for high efficient video coding standard, Alexandria Eng. J. (2016), http://dx.doi.org/10.1016/j.aej.2016.09.003

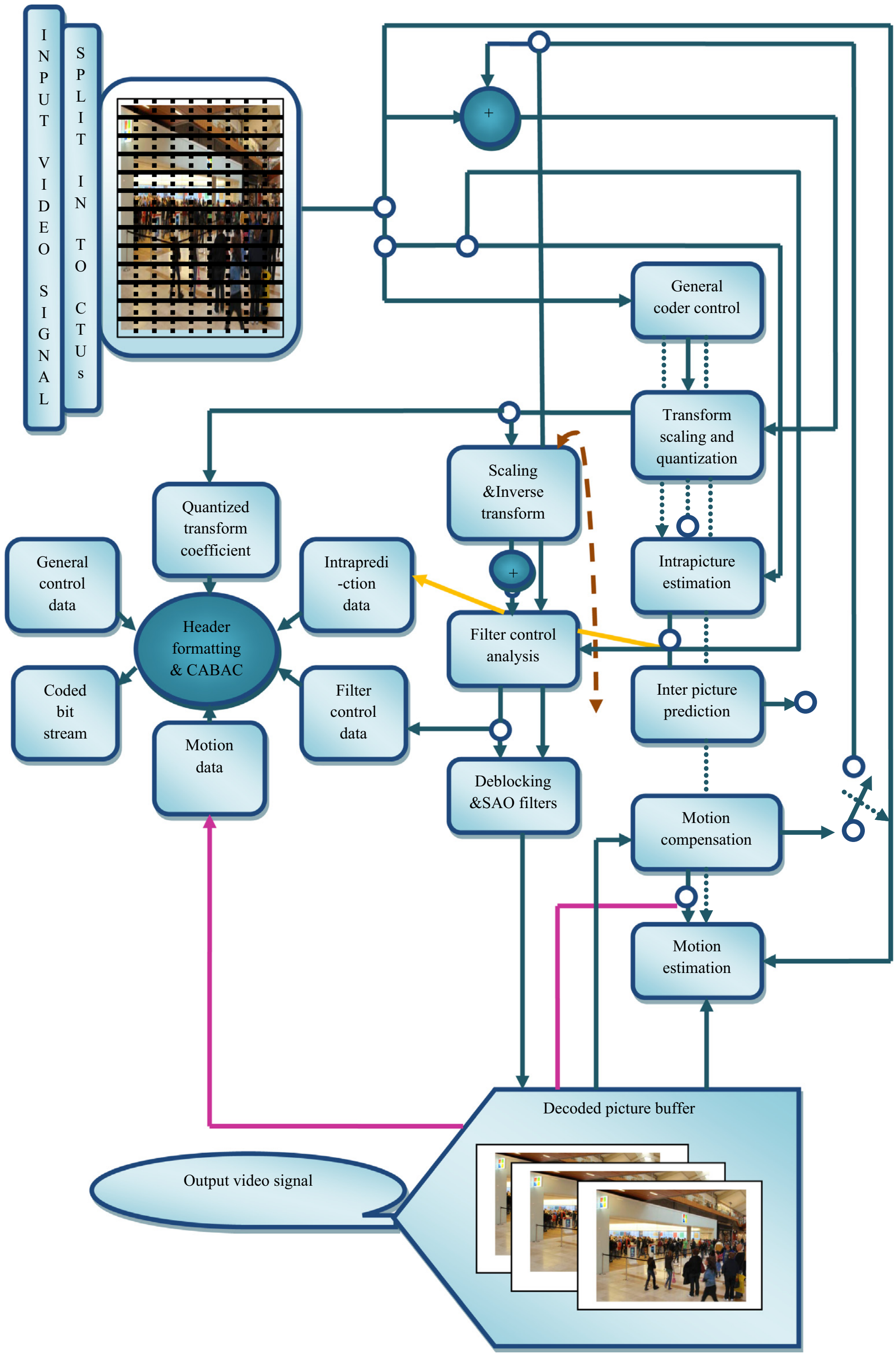

Figure 1 Architecture of High Efficient Video Coding standard.

direction was near to vertical. The vertical scan was applied, when the direction of prediction was near to the horizontal regions. For the directions, other than vertical and horizontal, the diagonal upright scan was used. Mostly, the scanning was performed in the 4×4 and 8×8 sub-blocks' TB sizes. The 4×4 diagonal upright scan was applied in the sub blocks for coding the 16×16 or 32×32 intra picture predictions. In HEVC, the last nonzero transform coefficient's position, sign bits, significant map and level of the transform coefficient can be transmitted. The sign bits were coded depending upon the number of the coded coefficients and the new compression effects were detected using the method of sign data hiding. From the parity of the total coefficient amplitudes, the first nonzero coefficients sign bit was detected, if the value of

Please cite this article in press as: B.S. Sunil Kumar et al., Improved entropy encoding for high efficient video coding standard, Alexandria Eng. J. (2016), http://dx.doi.org/10.1016/j.aej.2016.09.003

changes between the first and the last nonzero coefficients' scanning positions and the sign data hiding having two non-zero coefficients in 4×4 sub block are greater than 3.

4. Improved entropy encoding

4.1. Weighted entropy model

Let X be the set containing M video sequences $\{x_1, x_2, \ldots, x_M\}$, with individual x_k for $1 \leqslant k \leqslant M$. It can have categorical attribute vector of $[y_1, y_2, \ldots, y_N]^T$, where N represents the number of attributes and y_j had a domain value that can be estimated by $[y_{1,j}, y_{2,j}, \ldots, y_{n\,i,j}]$ for $1 \leqslant j \leqslant N$. Further, y_j represents the number of distinct values in the attribute y_j. Let us consider the attribute y_j as the random variable and so, the random vector $[y_1, y_2, \ldots, y_N]^T$ can be indicated as Y. The attribute x_i is represented as, $[x_{i,1}, x_{i,2}, \ldots, x_{i,m}]^T$.

The reverse sigmoid function of the entropy was used to weight the entropy of each attribute and so,

$$W_i = 1 - \log it^{-1}(w_i E_i) \tag{1}$$

$$W_i = 1 - \frac{1}{1 + e^{-w_i E_i}} \tag{2}$$

The weighted entropy model insists determining optimal w_i based on the pixel-wise correlation of the decoded video sequence with the original video sequence. Hence, the process of determining optimal w_i can be formulated as a maximization problem that can be given as follows:

$$w^* = \arg\max_{w_i} \sum_{l=1}^{M_s} \left(2\log x_l^{\max} - \left[\log \frac{1}{|x_l|} \sum_u \sum_v \left(x_l(u,v) - \widehat{x}_l(u,v)\right)^2 \right] \right) \tag{3}$$

where $x_l(u,v)$ and $\widehat{x}_l(u,v)$ refer to $(u,v)^{\text{th}}$ pixel element of a frame that corresponds to the l^{th} video sequence and the decoded video sequence, respectively.

4.2. Optimizing entropy weights

This paper exploited the firefly algorithm proposed by Xin-She Yang to optimize the entropy weights. In other words, the firefly algorithm is used to solve the objective model given in Eq. (3). This algorithm is closely related to the behaviour of flashing of the fireflies. The firefly algorithm is found to be effectively used in numerous applications [21–23]. The algorithm works based on three basic concepts such as,

(1) The fireflies are naturally unisex in character and so, one firefly will attract towards any other firefly.
(2) In flashing fireflies, the brightness generated is directly proportional to the attractiveness and the lesser brightness emitting firefly will move near the brighter firefly. The attractiveness and brightness will decrease with respect to increasing distance. It takes a random movement, if the brighter firefly is nil.
(3) The objective functions' landscape identifies the fireflies' brightness.

Since the attractiveness and the brightness are directly proportional to each other, the changes in the brightness β with respect to the distance r are given by, $\beta = \beta_0 e^{-\gamma r^2}$, where, β_0 represents the attractiveness at distance $r = 0$. If one firefly emits high brightness, the movement of the firefly i will be towards the brighter one j and it is given as follows:

$$w_i^{t+1} = w_i^t + \beta_0 e^{-\gamma r_{ij}^2}(w_j^t - w_i^t) + \alpha_t \in_i^t \tag{4}$$

where $\in_i^t$ and α_t represent the random vector that follows Gaussian distribution or the uniform distribution at time period t and randomization parameter, respectively. The second term of Eq. (4) mimics the attraction of fireflies. When $\beta_0 = 0$, the movement will be a random walk and if $\gamma = 0$, it gets converted into a variant of particle swarm optimization [21–23]. In addition to this, the $\in_i^t$ randomization will move towards the other distributions, known as Levy flights [21–23].

The pseudo code to optimize the entropy weights is illustrated in the below algorithm

Algorithm 1: Firefly algorithm to optimize entropy weights w_i	
1	Set t to zero
2	Generate initial fireflies w_i^0
3	$t \leftarrow t+1$
4	Determine the objective function
5	Update fireflies to determine w_i^t
6	If termination criteria is not met
7	Go to step 3
8	Else
9	Return w_i^t as w^*

According to the algorithm, the initial fireflies are arbitrarily generated within the interval [0, 1] and they are utilized to determine the objective value given in Eq. (3). The fireflies

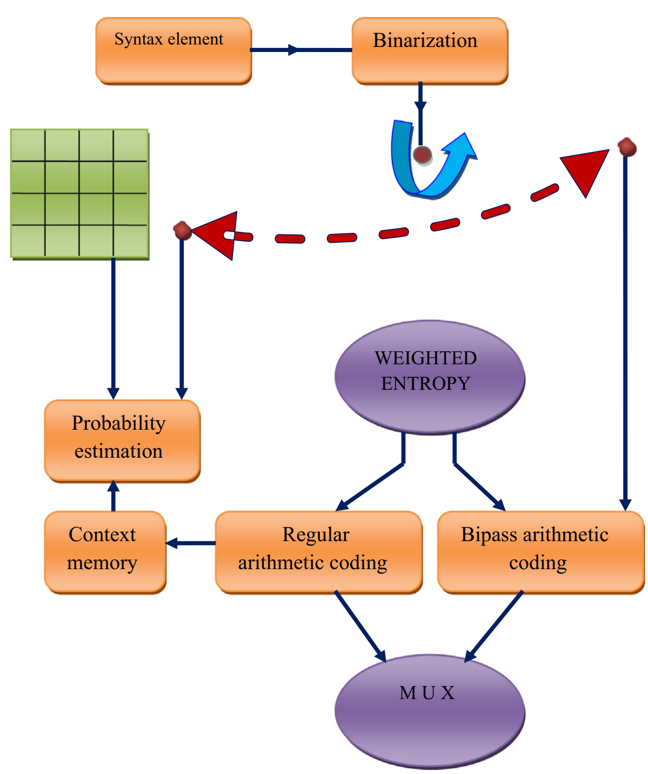

Figure 2 Architecture of the CABAC Encoder of HEVC.

Please cite this article in press as: B.S. Sunil Kumar et al., Improved entropy encoding for high efficient video coding standard, Alexandria Eng. J. (2016), http://dx.doi.org/10.1016/j.aej.2016.09.003

are updated using Eq. (4) to obtain the better fireflies that will be used to terminate the process, when satisfactory improvement is exhibited by the updated fireflies. The improved compression performance can be experienced using the weighted entropy and the HEVC architecture, as mentioned in Fig. 2.

5. Results and discussion

5.1. Experimental setup

The experimental study for the proposed and the standard entropy coding in HEVC standard is done with the selected eight video sequences available at http://www.cipr.rpi.edu/resource/sequences/sif.html in YUV file format. The eight video sequences are diversified by its contents and the number of frames such as coastguard, mobile, tennis, foreman, container, hall monitor, garden and football with 300, 140, 112, 300, 300, 300, 115 and 125 sequences, respectively. The resolution of the video sequences, foreman, container, hall monitor and coastguard is 352×288 and that of the video sequences, mobile, football, tennis and garden is 352×240. The PSNR of the decoded video sequences is analysed for understanding the performance of the encoded principles. The efficiency of the proposed method is evaluated by comparing with the standard encoding method.

5.2. PSNR analysis

The performance of the proposed method is analysed with the PSNR metric and the results are compared with the standard coding method. Fig. 3 represents the PSNR analysis for the video sequences, football, garden, mobile and tennis. Fig. 4 represents the PSNR analysis for the video sequences, coastguard, foreman, hall monitor and container. In Figs. 3 and 4, the PSNRs are plotted for four different transmitted bits that are being determined using the block sizes, 2, 4, 8 and 16, respectively. For instance, in the garden video sequence, the increase in the transmitted bits increases the PSNR that reaches 76 dB and 73.5 dB for the proposed and the standard method, respectively. But, in the football video sequence at a block size of 8, the PSNR values are 72 dB and 75 dB for the standard and the proposed method. The performance deviation between the proposed and the standard method is noted as 2.9%, 0.72%, 4.03%, 2.04%, 3.47%, 3.54%, 3.54%, 2.12% and -5.19%, with respect to the video sequences, hall monitor, foreman, tennis, garden, football, coastguard, container and mobile.

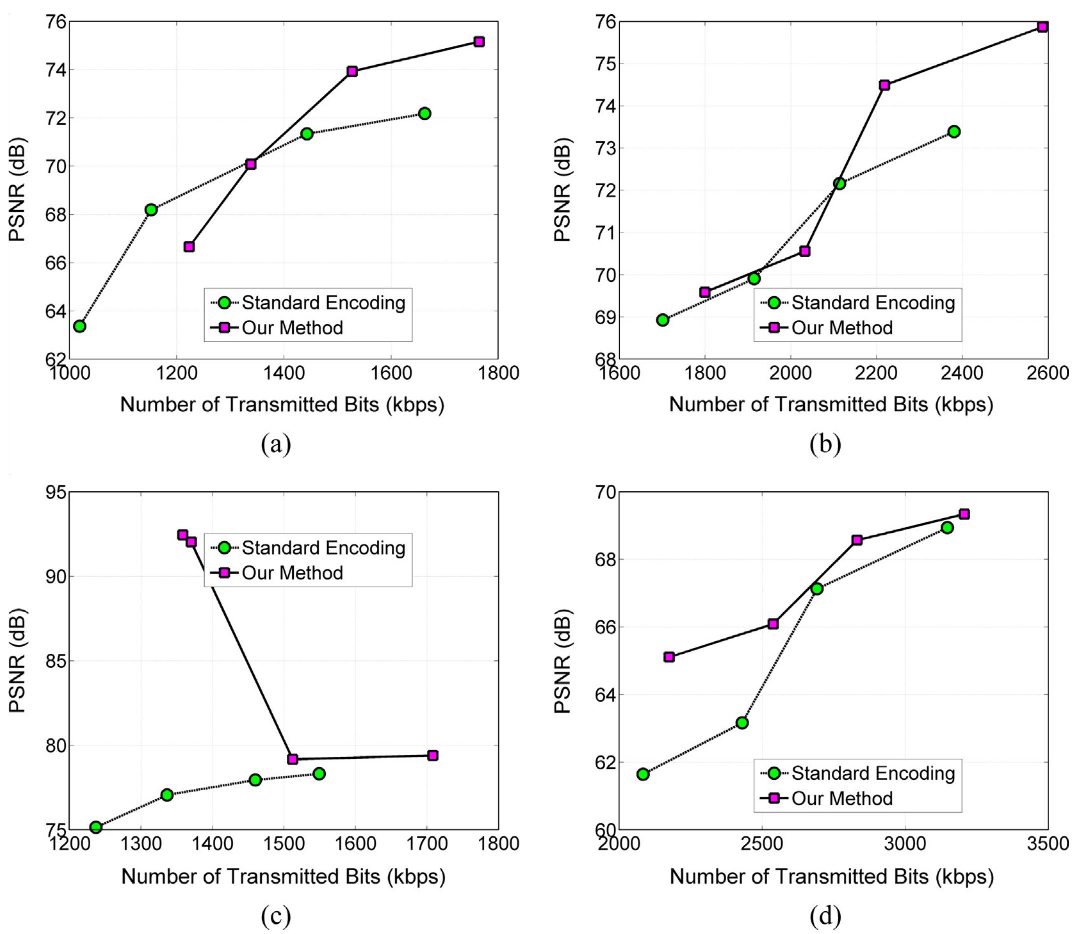

Figure 3 PSNR of the retrieved video sequences-(a) football, (b) garden, (c) mobile, and (d) tennis after the application of the improved as well as the standard entropy encoding principle of HEVC.

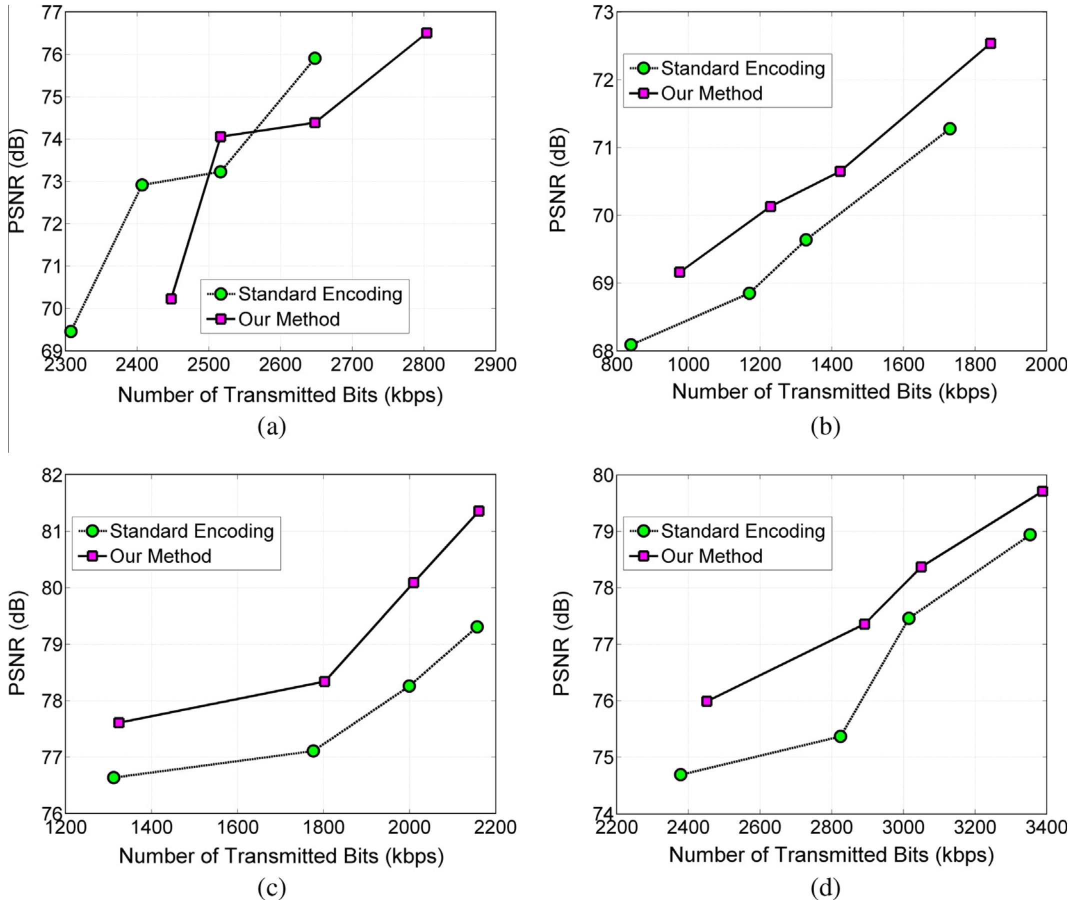

Figure 4 PSNR of the retrieved video sequences-(a) coastguard, (b) foreman, (c) hall monitor, and (d) container after the application of the improved as well as the standard entropy encoding principle of HEVC.

Although the performance deviation is negative at the initial phase for mobile sequence, the final phase tends to show high PSNR with an increase in the number of the transmitted bits. In case of the tennis and the container video sequence, the PSNR level is about 69.5 dB and 69 dB. In case of the foreman video sequence, the proposed outperforms the standard entropy encoding consistently and reaches 72.5 dB for a maximum number of transmitted bits. But, the consistency has been reduced, in case of the coast guard video sequence. The proposed method has managed to reach a highest PSNR of 76.5 dB. In the hall monitor video sequence, the proposed and the standard methods have achieved the PSNR of 81.5 and 79.2 dB, respectively.

When comparing the standard and the proposed entropy encoding procedure as per Figs. 3 and 4, the proposed entropy encoding maintains a linear relationship for the offered improvement over the standard entropy encoding. Though the results of all the video sequences, except the mobile video sequence, exhibit such linear relationship, it can be clearly viewed on foreman, hall monitor and container video sequences. In order to illustrate the relationship, let us consider the container video sequence (Fig. 4(d)). The standard encoding meets the PSNR of 74.5 dB, when transmitting at 2400 kbps. The PSNR has been increased to around 75.2 dB, when transmitting at 2800 kbps. The proposed encoding has achieved 76 dB and 77.2 dB, when transmitting at 2400 kbps and 2900 kbps, respectively. Approximately, the proposed encoding has achieved the PSNR of 77 dB, when transmitting at 2800 kbps of the video sequence. An increase in 400 kbps of the transmitting information results in an increase in the PSNR value by about 1 dB (approximately) using both the methods. This infers that the proposed encoding highly correlates with the principles of operation of the standard encoding with effective compression principles.

The performance of the proposed method and its comparison with respect to the statistical metrics such as mean, median, best, worst, and deviation are tabulated in Table 1. These metrics are determined based on the results of all the video sequences. In other words, the mean refers to the average PSNR of all the retrieved video sequences. The mean performance of the proposed method exhibits 1.93%, 2.1%, 4.5% and 69.7% improvement over the standard methods that correspond to the block size of 1, 2, 4 and 8, respectively. According to the median of performance with varying block sizes of 1%, 2%, 4% and 8, 2.06%, 2.4%, 1.26% and 1.04% improvement is noticed for the proposed method. While taking best as the measure for the block sizes of 1, 2, 4 and 8, the improvement is noted as 2.58%, 2.33%, 19.34% and 20.62% for the proposed method over the existing ones. When calculating the worst measure for the performance identification at varied block sizes of 1, 2, 4 and 8, the proposed method shows better performance with 0.58%, 2.14%, 4.62% and 5.61%

Please cite this article in press as: B.S. Sunil Kumar et al., Improved entropy encoding for high efficient video coding standard, Alexandria Eng. J. (2016), http://dx.doi.org/10.1016/j.aej.2016.09.003

Table 1 Mean encoding performance of proposed and standard encoding principle of HEVC.

Block size	Mean		Median		Best		Worst		Deviation	
	Standard	Proposed	Standard	Proposed	Standard	Proposed	Standard	Proposed	Standard	Proposed
1	74.78	76.23	74.65	76.19	79.31	81.36	68.94	69.34	3.90	3.98
2	73.39	74.95	72.69	74.44	78.26	80.09	67.13	68.57	4.14	4.08
4	71.57	74.83	71.41	72.31	77.11	92.03	63.17	66.09	4.91	8.05
8	69.74	73.35	69.19	69.91	76.64	92.45	61.65	65.11	5.48	8.81

Table 2 Computation time incurred by proposed and standard encoding principle of HEVC.

Block size	1		2		4		8	
Method	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
Sequence 1	3,125,492	3,133,454	3,954,164	3,975,798	4,565,415	4,576,468	4,854,611	4,897,649
Sequence 2	2,564,164	2,574,987	2,665,464	2,667,569	2,748,745	2,765,765	2,965,414	2,965,636
Sequence 3	4,165,445	4,152,343	4,274,642	4,235,496	4,379,577	4,389,465	4,478,989	4,512,485
Sequence 4	2,477,663	2,545,416	2,577,169	2,671,150	2,698,715	2,714,523	2,736,917	2,764,842
Sequence 5	4,578,152	4,625,414	4,764,423	4,715,649	4,978,548	4,999,496	5,074,643	5,124,414
Sequence 6	4,639,711	4,641,811	4,781,961	4,758,414	4,871,490	4,941,174	5,063,781	5,124,851
Sequence 7	4,268,954	4,275,151	4,316,474	4,334,741	4,516,574	4,684,715	4,795,716	4,864,841
Sequence 8	5,127,471	5,145,451	5,295,441	5,384,142	5,299,741	5,348,841	5,397,174	5,434,548

Table 3 Performance improvement over standard encoding principle and the computation cost incurred for the improvement.

Block size	1		2		4		8	
Improvement metrics	PSNR	Time	PSNR	Time	PSNR	Time	PSNR	Time
Video sequence 1	4.12	0.25	3.63	0.54	2.77	0.24	5.19	0.88
Video sequence 2	3.37	0.42	3.22	0.07	0.92	0.61	0.95	0.007
Video sequence 3	1.37	−0.31	1.56	−0.91	19.41	0.22	23	0.74
Video sequence 4	0.58	2.73	2.14	3.64	4.62	0.58	5.61	1.02
Video sequence 5	0.79	1.03	1.58	−1.02	1.56	0.42	1.1	0.98
Video sequence 6	1.76	0.04	1.45	−0.49	1.85	1.43	1.57	1.2
Video sequence 7	2.58	0.14	2.33	0.42	1.59	3.72	1.26	1.44
Video sequence 8	0.97	0.35	1.17	1.67	2.64	0.92	1.74	0.69

improvement over the standard encoding. The deviation actually refers to the reliability of the achieved performance and hence, it is expected to be less. Despite the fact that the proposed method has an increased deviation, such lagging can be neglected because of the higher rate of improvement that is achieved in all the other cases.

5.3. Complexity analysis

The computational time is estimated and tabulated in Table 2 for the selected eight video sequences. The computational time incurred by the proposed method is higher than the standard encoding principle in all the video sequences, except for the block size of 2 in video sequences 3, 5 and 6. Increase in the computational time is due to more steps involved in the proposed encoding. The performance of the proposed method with respect to the computational time and PSNR is given in Table 3. The numerical value for PSNR and the computational time refers to the rate of increase by the proposed encoding over the standard encoding. They state that the proposed encoding incurs increased computational time over the standard encoding. However, the rate of increase in the computational time is relatively lesser than the rate of improvement in PSNR offered by the proposed encoding. For instance, the proposed encoding has incurred 0.25% more computing time than the standard encoding and has offered 4.12% more PSNR. Moreover, the proposed encoding has achieved such PSNR improvement in reduced time at few instances such as, the block size of 2×2 of the video sequence 3.

6. Conclusion

This paper has introduced the weighted entropy encoding for the HEVC coding standard. The selected standard video sequence has been experimentally analysed and the efficiency of the proposed method has been studied. The metric measures- mean, median, worst, best and deviation have been evaluated for both the proposed and the standard encoding methods. Highest improvement has been observed for the proposed method-69.7% for mean, 2.4% for median, 20.62% for best, and 5.61% for worst. The PSNR analysis has been done for finding the encoding performance, where we have asserted the performance of the proposed encoding method. The computational time taken for the proposed method has remained higher. But, the encoding performance has been much higher than that of the standard ones that makes the computational complexity negligible. This evaluation has proved the importance of the improved encoding method in the HEVC standard.

References

[1] G. Tech, Y. Chen, K. Muller, J.R. Ohm, A. Vetro, Y.K. Wang, Overview of the multiview and 3D extensions of high efficiency video coding, IEEE Trans. Circuits Syst. Video Technol. 26 (1) (2016) 35–49.

[2] A.J.D. Honrubia, J.L. Martinez, P. Cuenca, J.A. Gamez, J.M. Puerta, Adaptive fast quadtree level decision algorithm for H.264 to HEVC video transcoding, IEEE Trans. Circuits Syst. Video Technol. 26 (1) (2016) 154–168.

[3] J. Sole, R. Joshi, N. Nguyen, T. Ji, M. Karczewicz, G. Clare, F. Henry, A. Duenas, Transform coefficient coding in HEVC, IEEE Trans. Circ. Syst. Video Technol. 22 (12) (2012) 1765–1777.

[4] T. Nguyen, P. Helle, M. Winken, B. Bross, D. Marpe, H. Schwarz, T. Wiegand, Transform coding techniques in HEVC, IEEE J. Select. Topics Signal Process. 7 (6) (2013) 978–989.

[5] N. Hu, E.H. Yang, Fast mode selection for HEVC intra-frame coding with entropy coding refinement based on a transparent composite model, IEEE Trans. Circuits Syst. Video Technol. 25 (9) (2015) 1521–1532.

[6] C.H. Yeh, T.Y. Tseng, C.W. Lee, C.Y. Lin, Predictive texture synthesis-based intra coding scheme for advanced video coding, IEEE Trans. Multimedia 17 (9) (2015) 1508–1514.

[7] M. Wang, K.N. Ngan, H. Li, An efficient frame-content based intra frame rate control for high efficiency video coding, Signal Process. Lett. IEEE 22 (7) (2014) 896–900.

[8] W. Han, J. Min, I. Kim, E. Alshina, A. Alshin, T. Lee, J. Chen, V. Seregin, S. Lee, Y. Hong, M. Cheon, N. Shlyakhov, K. McCann, T. Davies, J. Park, Improved video compression efficiency through flexible unit representation and corresponding extension of coding tools, IEEE Trans. Circuits Syst. Video Technol. 20 (12) (2012) 1899–1909.

[9] L. Xiang, M. Wien, J.R. Ohm, Rate-complexity-distortion optimization for hybrid video coding, IEEE Trans. Circuits Syst. Video Technol. 21 (7) (2011) 957–970.

[10] G. Correa, P. Assuncao, L. Agostini, L.D.S. Cruz, Performance and computational complexity assessment of high-efficiency video encoders, IEEE Trans. Circuits Syst. Video Technol. 22 (12) (2012) 1709–1720.

[11] F. Bossen, B. Bross, K. Suhring, D. Flynn, HEVC complexity and implementation analysis, IEEE Trans. Circuits Syst. Video Technol. 22 (12) (2012) 1685–1696.

[12] G. Sullivan, J. Ohm, W.-J. Han, T. Wiegand, Overview of the high efficiency video coding (HEVC) standard, IEEE Trans. Circuits Syst. Video Technol. 22 (12) (2012) 1649–1668.

[13] G.J. Sullivan, J.M. Boyce, Ying Chen, J.R. Ohm, C.A. Segall, A. Vetro, Standardized extensions of high efficiency video coding (HEVC), IEEE J. Select. Topics Signal Process. 7 (6) (2013) 1001–1016.

[14] Yongseok Choi, Jongbum Choi, High-throughput CABAC codec architecture for HEVC, Electron. Lett. 49 (18) (2013) 1145–1147.

[15] Dajiang Zhou, Jinjia Zhou, Wei Fei, S. Goto, Ultra-high-throughput VLSI architecture of H.265/HEVC CABAC Encoder for UHDTV applications, IEEE Trans. Circuits Syst. Video Technol. 25 (3) (2015) 497–507.

[16] T. Shanableh, E. Peixoto, E. Izquierdo, MPEG-2 to HEVC video transcoding with content-based modeling, IEEE Trans. Circuits Syst. Video Technol. 23 (7) (2013) 1191–1196.

[17] Kemal Ugur, Kenneth Andersson, Arild Fuldseth, Gisle Bjontegaard, Lars Petter Endresen, Jani Lainema, Antti Hallapuro, Justin Ridge, Dmytro Rusanovskyy, Cixun Zhang, Andrey Norkin, Clinton Priddle, Thomas Rusert, Jonatan Samuelsson, Rickard Sjoberg, Zhuangfei Wu, High performance, low complexity video coding and the emerging HEVC standard, IEEE Trans. Circuits Syst. Video Technol. 20 (12) (2010) 1688–1697.

[18] Mahsa T. Pourazad, Colin Doutre, Maryam Azimi, Panos Nasiopoulos, HEVC: the new gold standard for video compression: how does HEVC compare with H.264/AVC?, IEEE Consum Electron. Mag. 1 (3) (2012) 36–46.

[19] Jani Lainema, Frank Bossen, Woo-Jin Han, Junghye Min, Kemal Ugur, Intra coding of the HEVC standard, IEEE Trans. Circuits Syst. Video Technol. 22 (12) (2012) 1792–1801.

[20] Min Gao, Xiaopeng Fan, Debin Zhao, Wen Gao, An enhanced entropy coding scheme for HEVC, Sign. Process. Image Commun. 44 (2016) 108–123.

[21] B.R. Rajakumar, Aloysius George, On hybridizing fuzzy min max neural network and firefly algorithm for automated heart disease diagnosis, in: 2013 Fourth International Conference on Computing, Communications and Networking Technologies (ICCCNT), 2013, pp. 1–5.

[22] Ming-Liang Gao, Xiao-Hai He, Dai-Sheng Luo, Jun Jiang, Qi-Zhi Teng, Object tracking using firefly algorithm, IET Comput. Vision 7 (4) (2013) 227–237.

[23] Ilhan Aydin, A new approach based on firefly algorithm for vision-based railway overhead inspection system, Measurement 74 (2015) 43–55.

Please cite this article in press as: B.S. Sunil Kumar et al., Improved entropy encoding for high efficient video coding standard, Alexandria Eng. J. (2016), http://dx.doi.org/10.1016/j.aej.2016.09.003