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Low complexity rate control for versatile video coding with hybrid Lagrange multiplier

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ABSTRACT

Versatile video coding (VVC) has a notable increase in encoding efficiency over high efficiency video coding (HEVC) but bandwidth and storage are limited in real-world video applications, so rate control is crucial. Even if VVC shows a notable increase in encoding capacity over HEVC, the rate control may create fluctuations in video quality and computational complexity. This fluctuation can have a significant impact on the watching experience, particularly in low-bitrate settings. The rate control variables of the consistent resolution and the decreased resolution are proposed in order to make the rate control method hybrid to consistent resolutions and reduce computational complexity. To achieve optimal coding parameters, the frames with varying resolutions Lagrange multiplier (λ), skip coding tree unit (CTU) and quantization parameter (QP) are combined. After evaluation, the average encoding time savings (T_{saving}) were found to be 19.49%, with a Bjontegaard delta bit rate (BDBR) of -0.44% indicating insignificant quality loss.

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NOMENCLATURE

R_n : The allocated bit rate
R_{Tar} : The bit rate target
D : Distortion
C, K : Model parameters associated with the source's characteristic
α, β : Video source-related factors, updated based on the bitrate
QP : Quantization parameter
m : The index of R-D model parameter
n : The index of CTU
RD_{Cost} : Rate-distortion cost
λ_l^* : The optimum amount Lagrange multiplier
$g_{(n)}$: Noisy subgradient

1. INTRODUCTION

The increasing popularity of video applications has increased the demand for more effective video coding technologies. In practical video coding applications, rate control is crucial because of bandwidth and storage budget constraints. Rate control is a fundamental tool in video coding and is vital to realistic video coding systems because of bandwidth or storage limitations in real-world applications. Its goal is to reduce distortion in compressed videos while adhering to bit-rate restrictions. Rate control (RC), one of the fundamental components of versatile video coding (VVC), allows for more precise bit allocation and is particularly important for reducing distortion [1]–[3]. Consequently, when the bits of target in the rate control methods are low enough at the frame level, downsampling-based coding ought to be advantageous.

Rate control has been extensively researched over the last few decades for various applications of video coding standards. The fundamental idea of bit allocation is to assign a greater number of bits to high-complexity frames and a lesser number to low-complexity frames to ensure uniform visual quality. Depending on the intricacy of the current frame, quantization parameter (QP) is dynamically changed for every frame. Therefore, the complexity measurement model for each frame should be proposed before determining QP for each frame. Achieving the target bitrate and reducing distortion are the two goals of rate management. Generally, there are three types of typical rate control models R-Q, ρ domain, and R-λ models. Studies [4], [5] introduced the R-λ model, and it was incorporated into the high efficiency video coding (HEVC) standard software HEVC test model (HM) [6], [7]. The R-λ model offers a favorable trade-off between the accuracy of parameter amounts and prediction when compared to classic rate control models, which could help improve parameter stability. Following that, HEVC has been the subject of much research based on the R-λ model [8]–[14]. The fundamental premise of the Q-domain rate control techniques [15]–[17] is that, given the constraints of the desired bitrate R, the optimal coding performance can be attained with a carefully selected quantization parameter Q.

There are several modes sets to choose from in the video coding system, which results in an enormous number of rate and distortion (R-D) data pairs. However, the goal of rate control is to select the best mode for a desired bit rate to minimize distortion at the specified bit rate. It can be transformed into an unconstrained form after being formulated by a constrained optimization problem. Two-pass rate control techniques [18], encoded the sequence twice. Motion vectors, the number of discrete cosine transform (DCT) coefficients, header lengths, the number of residual bits per frame, and other statistical information were gathered during the first run and watched how the sequence manifested itself. Using the parameters collected in the first pass, the QP is improved in the second pass. Most two-pass techniques are used for non-real-time, fixed-sized storage applications such as online video streaming and digital video discs (DVDs), whereas one-pass techniques are more appropriate for real-time applications. However, especially when there are major motions or scene changes, the distortion of the co-located coding tree unit (CTU) may be very different from the real distortion of the CTU. This is because the approach is still solely focused on inter-CTU rate control.

A similar study by Fu *et al.* [19] proposed a rate control with resolution changes for VVC. Using a λ-domain rate control approach that allows for resolution modifications, a frame's coding resolution is calculated based on its properties. The rate control variables for the low resolution and high resolution are changed independently in order to adapt the rate control technique to mixed resolutions. Hybrid Laplace distribution-based low complexity rate-distortion optimized quantization was proposed by Cui *et al.* [20], they suggested a low-complexity rate-distortion optimized quantization (RDOQ) approach by using a hybrid Laplace distribution to model the statistics of the transform coefficients. This way, depending on the coefficient distribution, distortion models and block level rate are specifically developed. Thus, by maximizing the RD performance of the entire block, the ideal quantization levels may be found directly, and the laborious RD cost computations can eventually be avoided. In a related study, Liao *et al.* [21] suggested frame-level rate control in flexible video coding using content-adaptive rate-distortion modeling. For one-pass video coding, they proposed high-order R-D models and corresponding frame-level RC algorithms. Finally, the quadratic R-D model is incorporated into frame-level RC in the VVC test model (VTM) and a content-adaptive model selection is made between the first-order and second-order R-D models.

An RD parameter updating technique was given by Li *et al.* in [22], where they also examined the quality dependency between frames. A frame-level recursive Bayesian estimation (RBE) based constant bit-rate (CBR) control technique was presented in [23]. As it stands, the model of hyperbolic R-D is highly accurate, thus creating a new version of the model will not likely increase accuracy much further. The RBE, utilizing updated stages and alternating prediction, could assess bit rates and distribute target bit rates based on the distortion variations of the recently encoded frames. Their methodology reduces the multi-objective optimization challenge to a single-objective issue aimed at minimizing average distortion and quality variation within the limited bit rate. Subsequently, a dual-phase approach grounded in the D-λ model was suggested to get the ideal resolution. This approach yields a solution that assigns the bit rate to each CTU once for all. Unfortunately, the approach necessitates two-pass coding, and its high cost of complexity prevents it from being applied to real-time requirements in RC circumstances.

In this study, we propose new low complexity rate control method hybrid, contributing to reduce computational complexity and consistent resolutions. The rate control mode decision strategies using texture detail scenarios' threshold values. To reduce computing requirements and expedite the rate control mode determination process, an efficient termination and bypass technique is employed. The average encoding time savings (T_{saving}) were found to be 19.49%, with a Bjontegaard delta bit rate (BDBR) of -0.44% indicating insignificant quality loss.

2. LAGRANGE MULTIPLIER

According to rate-distortion theory, there is an optimal compression rate, R(D), given an acceptable distortion D. This function is known as the rate-distortion (R-D) function, and it is convex and gradually decreasing. A decent video encoder must determine the optimal set of parameters to reduce distortion while adhering to a specific bit rate restriction. The following allocation of resources problem can be resolved by an optimal rate-control system, assuming that N coding units will make up the full video [24].

$$\min_{\{(m_n, q_n)\}} \sum_{n=1}^{N} D_n(m_n, q_n)$$

$$subject\ to\ \sum_{n=1}^{N} R_n(m_n, q_n) \leq R_{Tar} \tag{1}$$

The encoder creates a bitstream by compressing the input CTU pixels. The λ-value is updated using the produced bit number R and distortion D. The values R and D are regarded as random variables since they vary from CTU to CTU. The following issue is resolved by reformulating the rate control procedure. Generally, λ is used by video encoders to adjust R and D. For simple implementations, video encoders usually use empirically predetermined λ coefficients for QP values, although λ can be determined theoretically. A rate controller uses the R-QP-λ relation to calculate a QP based on the intended bit rates. Next, the QP is used in the encoder in the video compression process. In this encoder, the RDO computes the joint R-D cost between R and D using λ to identify the best encoding modes and encoding settings. Finally, the encoder adds residues (non-texture bits) and various parameter values (texture bits) to the output bit-streams. It is noticed that the λ employed in HEVC is nearly identical to VVC. For practical purposes, the quantization parameter factor (QP_f) is defined as 0.85. The slice-type in VTM defines λ as (2):

$$\lambda = QP_f \,.\, 2^{(QP-12)/3} \tag{2}$$

It is observed that QP models λ independent of the video content. Furthermore, for appropriate bit allocation in hierarchical forecasting structures, it is generally expected that a higher layer's λ value will be larger than its lower layer's (*i.e.*, a higher layer's QP value will be larger than a lower layer's). In this study, we approximate the λ value using the stochastic subgradient approach and $g_{(n)}$ (noisy subgradient). The n^{th} iteration updates the value of λ by (3):

$$\lambda_{(n+1)} = \lambda_{(n)} + \alpha_n \, g_{(n)} \tag{3}$$

This study presents a uniform quality criterion for the rate control model, and the R-D optimization procedure yields a generic optimal solution with the least perceptual distortion variation restriction. The majority of R-D optimization strategies are compatible with the solution. Ultimately, comprehensive tests are carried out together with in-depth analysis to demonstrate the effectiveness of the suggested algorithm. The analysis leads to the proposal of the *R-λ* rate control model. Finding an accurate estimation for the ideal R-D curve is important for λ value prediction. R and D stand for the consumed bits and distortion, respectively. The consumed bits in this case ought to be close to the target bits. The Lagrange multiplier, or λ, represents the *R-D* curve's slope. The mode choice will be guided by λ once it has been established. The derivation of λ is crucial in the λ-domain rate control techniques. The link between R and D is characterized by the hyperbolic function in [25]–[29]. Since λ represents the *R-D* curve's slope, it may be written as (4):

$$\lambda = -\frac{\partial D}{\partial R} = C\,K\,.\,R^{-K-1} \triangleq \alpha R^{\beta} \tag{4}$$

where α and β are the video source-related factors. To get a more accurate estimate of the bitrate, α and β get updates according to the bitrate and λ of the coded frames.

Since the variation in quality in a compressed video signal has a substantial effect on human visual perception, consistent quality management seeks to minimize the distortion variation over video frames within the constraints of frame rate, bandwidth, and delay required. Based on the previously provided rate models and distortion, the optimal bit allocation problem for the video coding system replacing Di and Ri from the standpoint of minimizing average (MINAVE) distortion can be phrased as (5):

$$\lambda^*_{1..N} = \underset{\lambda^*_{1..N},}{\arg\min} \ \frac{1}{N}\sum_{l=1}^{N} D_l^{curr}(\lambda_l^{curr})$$
$$\sum_{l=1}^{N} R_k\,(\lambda_k^{curr}) \le R_{max} \tag{5}$$

where λ_l^* is the optimum amount of λ_l^{curr}. The technique proposes to loosen the constraint $\sum_{l=1}^{N} R_k(\lambda_l^{curr}) \le R_{max}$ with the inequality of geometric and arithmetic means, based on the observation that the budget is a power function concerning the variable λ_l^{curr}. It must, however, take into account the frame budget and buffer state; as a result, it must modify λ^* to ensure that $\sum_{l=1}^{N} R_k(\lambda_l^{curr}) \le R_{max}$ in the actual encoder video coding.

The encoder can choose the best resolution by combining downsampling and coding distortions, which are impacted by frame spatial features, using the coding resolution in VVC. Before encoding, the frame to be coded is down and up-sampled. The up-sampled frame is then compared to the original frame to establish the downsampling distortion. When the distortion of downsampling is below a preset threshold, the downsampling-based coding is subsequently applied. Based on the statistical data analysis and earlier research [19], the threshold can be determined using QP.

$$D_{TH} = e^{0.175\,.QP\,-\,3.5} \tag{6}$$

Even with great attempts to improve rate control of R-λ base, the parameters are still calculated by combining both skip and non-skip blocks, which results in an imprecise estimation of the VVC standard. Skip information extraction can help with bit allocation at the CTU level in addition to helping with parameter estimation and the R-D curve.

$$B_{tar\ avg} = \frac{R_{tar}}{CTU_{Number}} \tag{7}$$

$$B_n = \frac{R_{tar} - \sum_{m=1}^{n-1} R_m}{CTU_{Number} - 1} \tag{8}$$

The average budget allotted for every CTU is to be the target bits B_{tar} (5). When the starting λ value is not near the ideal value, the fluctuating result bits may diverge from the intended B_{tar}. As a result, we adjust the target bits for the n^{th} CTU dynamically and assign the remaining bit budget to the last CTU (6). R_m must incorporate the bits from the header information produced by the m^{th} CTU as well as the texture residual to estimate the target bit with any degree of accuracy. Every one of the 64 possible QPs is examined to see which is the best QP at the lowest RD_{cost}. Tested are the following 25 video sequences: Class A1, A2, B, C, D, E, and F. The goal of selecting these sequences was to cover the entire spectrum of motion activity characteristics, ranging from low to high. There are seven constant λ values for each series, ranging from 5 to 400. We search for and keep the best QP value for each fixed λ value. All distributions, it turns out, center on their peaks. We gather the most likely QPs and their λ values for every test video sequence.

3. METHOD

Provide rate control for video coding consists of two parts: the rate control model and the target bit allocation. In the former, parameters are adjusted by rate control designs to get an actual number of coded bits that is as close as possible to the target bit budget for base coding units, frames, and GOPs; in the latter, the target bitrate is assigned through the group of pictures (GOP) level to the frame and CTU levels in alignment with a minimum amount of distortion. Target bit implementation aims to convert target bit allocation value into quantization parameter QP value; QP determines both the compression ratio and the final encoding rate. Following the quantization parameter's value determination, the relevant parameters must be updated and adjusted. Target bit implementation is finished at the picture and CTU layers, and the implementation concepts are essentially the same.

The Lagrange multiplier was altered to improve the quality deviation based on the distortions of earlier CTUs. However, especially when there are notable motions or scene changes, the distortion of the co-located CTU may differ greatly from the real distortion of the current CTU. This is because the approach is still solely focused on the inter-CTU rate control, a two-pass rate control technique that uses downsampled video coding to provide consistent quality. The Lagrange multiplier is applied after the first pass to minimize quality fluctuations. It is evident that while these current consistent quality-oriented algorithms can aid in smoothing the quality of compressed video, the majority of them focused on the variation in quality between interframes rather than the variation in quality inside a single frame.

Rate control may cause variations in video quality since the surrounding areas are quantized into different quality levels. This can have a significant impact on the watching experience, particularly in low bitrate settings. Based on the calculation of frame complexity, we suggest a fast and accurate technique for allocating bits at the frame layer in VVC rate regulation. The target bit can be assigned to each frame in a GOP according to the predicted complexity. Comparing the suggested algorithm to other available techniques, experimental results demonstrate that it may greatly reduce the quality variation in the frame layer.

Figure 1 shows the proposed method algorithm flowcharts of the rate control mode decision in VTM. The value of Lagrange multiplier (λ) is calculated from (2) and the projected R-D parameters, C, R and K, come from (4). The values of C and K are the model parameters associated to the characteristic of the input. When there are several coding stages and frames with multiple mixed skip CTU, the frame level with bit allocation needs to be taken into consideration more thoroughly. Each CTU is initially thought of as the standard, or non-skip block. Initial values are provided for these two parameters, and they will be adjusted continuously in the next step. If the area falls below a predefined threshold (Th), this particular CTU will be managed as a standard CTU. The skip CTU would be interpreted otherwise. After the current frame has completed encoding, distortion, the pixels, and spent bits in the standard CTU will participate in the frame-level R-D variable update. The data in skip CTU will not be used.

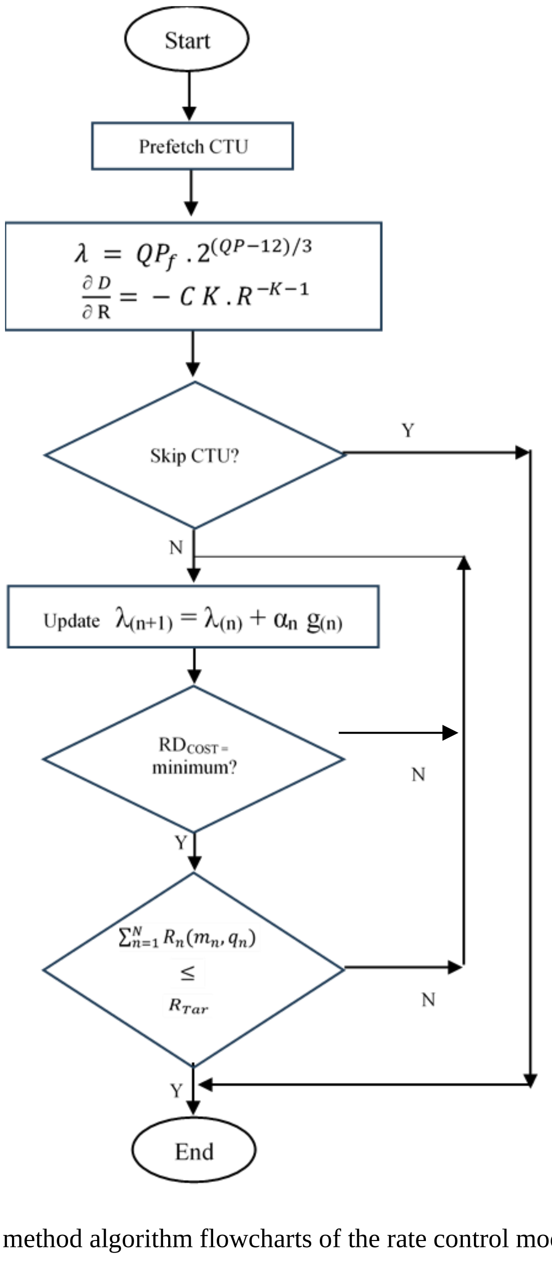

Figure 1. Proposed method algorithm flowcharts of the rate control mode decision in VTM

When the mode decision is to skip CTU, updating the λ value can be pre-eliminated when a CTU is classified as non-SKIP. Th_L is equal to 0.001 and Th_U is 0.9 [30] and can be modified to produce different outcomes [31]. When the amount of bit per pixel (bpp) as measured by R exceeds an upper threshold Th_U or falls below a lower threshold Th_L, the area ratio of Skip CTU in the coded CTU.

For the test, several video sequences from Classes A1, A2, B, C, D, E, and F are selected, containing all frames at default frame rates. The fix QP method refers to four fixed QP 22, 27, 32 and 37 that are set to do video coding on sequences without rate control initially while taking low bitrate consideration into account. The Fix QP-based compression bitrates are then established as the desired bitrates for every rate control method used in this study. Comparisons with other approaches are anchored by the VTM 14.2 rate control method's performance. It should be noted that the default techniques for rate control are still frame level and GOP level. The next subsections compare and provide detailed experimental data for all rate control algorithms, including the quality variance, the objective and perceptual R-D efficacy, and the RC accuracy at different levels, and the subjective level of performance with coding complexity.

When α is fixed, a bigger value corresponds to a faster approach of λ_i to the optimum. However, if λ varies more about the convergent value, the coding becomes less effective. We adaptively vary the value of λ in the VTM reference software's encoding process to explore the implications of various step sizes. Algorithm 1 explains the low complexity rate control for the VVC method.

Algorithm 1. Pseudocode of low complexity rate control for VVC

Input: GOP, Frame, CTU;
Output: Mode decision, QP, CU, λ;
Step 1. Prefetch CTU;
Step 2. Calculate $\lambda = QP_f \,.\, 2^{(QP-12)/3}$;
Step 3. Calculate C, R and K from (4);
Step 4. if skip CTU jump to end;
Step 5. Update $\lambda_{(n+1)} = \lambda_{(n)} + \alpha_n g_{(n)}$
Step 6. if current λ decision = $BestRD_{COST}$ then;
Step 7. if $\sum_{n=1}^{N} R_n(m_n, q_n) \leq R_{Tar}$ then;
Step 8. end if
Step 9. jump to step 3
Step 10. return mode decision, QP, λ;
Step 11. end

For accurate RD cost calculation, complexity reduction necessitates the creation of precise rate-distortion models. Much less attention has recently been paid to optimizing the quantization process, despite the fact that numerous precise rate distortion models have been put out for the fast mode determination and rate control domains. Through the establishment of specially created rate and distortion models based on the proposed model approach, a low complexity algorithm is proposed in this study. Consequently, with knowledge of the distortion and rate models as functions of the residual statistics and quantization parameters, it is possible to successfully avoid the computationally intensive search for the optimal quantized coefficients. Figure 2 illustrates the visual comparisons of FourPeople sequence between the reconstructed frames obtained using the default rate control in VTM 14.2 in Figure 2(a) and after reconstructed using our rate control approach in Figure 2(b). The comparison of subjective visuals shows insignificant quality loss and BDBR as shown in Table 1.

(a) (b)

Figure 2. The comparison of subjective visual of FourPeople sequence (a) default VTM and (b) our proposed method

Table 1. The result of the proposed method

Class	Sequence	Proposed method		
		BDBR (%)	T_{saving} (%)	B_{err} (%)
A1	Tango1	-0.09	17.48	0.078
	FoodMarket4	0.28	17.79	0.093
	Campfire	0.41	22.47	0.53
A2	CatRobot	-0.032	17.58	0.076
	DaylightRoad2	0.35	18.51	0.067
	ParkRunning3	-0.09	16.42	0.025
B	Kimono	-1.36	21.11	0.12
	ParkScene	0.08	20.13	0.095
	Cactus	-0.54	19.82	0.12
	BasketballDrive	0.173	16.87	0.09
	BQTerrace	0.28	20.21	0.166
C	BasketballDrill	-0.98	18.79	0.32
	BQMall	-0.31	21.65	0.32
	PartyScene	-1.21	21.89	0.18
	RaceHorsesC	0.13	16.34	0.21
D	BasketballPass	-0.34	17.43	0.62
	BQSquare	-0.87	21.79	0.48
	BlowingBubbles	-0.11	22.19	0.35
	RaceHorses	-0.09	14.98	0.87
E	FourPeople	-0.33	22.98	0.55
	Johny	-0.76	22.87	0.645
	KristenAndSandra	-1.24	18.13	0.78
F	BasketballDrillText	-0.89	16.21	0.39
	SlideEditing	-0.16	20.95	0.35
	SlideShow	-0.88	22.78	0.65
Average		-0.44	19.49	0.327

4. RESULT AND DISCUSSION

A comparison with the rate control method found in VTM 14.2 is done in order to confirm the effectiveness of the suggested rate control strategy. The CTC for low delay (LD) and all intra (AI) configurations are used for the simulations. As downsampling-based coding is often advantageous for low bitrates and high-resolution sequences with test QPs set to {22, 27, 32, 37}.

To attain the goal bitrate used in our research, the test sequences are encoded using the original VTM 14.2 without the proposed rate control mode by the aforementioned test circumstances. The resulting target bitrate is then utilized as the input target bitrate for "Proposed RC" and "RC in VTM-14.2" after being rounded to the nearest integer. Since the objective of rate control is to achieve the desired bitrate and minimize distortion, the rate control algorithm is evaluated using both bitrate error and R-D performance. In this case, the bitrate error can be computed using:

$$B_{err} = \frac{|B_{out} - B_{tar}|}{B_{tar}} \times 100\% \tag{9}$$

where B_{tar} is the designated target bitrate and B_{out} is the encoder's output bitrate. In this paper, VTM 14.2 was tested on a PC running Linux Ubuntu 20.04.4 LTS with an Intel® CoreTM i7-67000T Core @ 2.80 GHz processor. Thirty frames are examined for each sequence in the tests, which are conducted using the JVET common test conditions. Table 1 displays the result of the proposed method. The default test conditions used in this paper are common test conditions with quantization parameter (QP): 22, 27, 32, 37, and all intra (AI). The coding performance is measured using BDBR, and the encoding time savings (T_{saving}) are compared to the original VTM program ($Time_{VTM}$) and the suggested technique ($Time_{proposed}$). The following provides the average encoding time savings, which is a measure of complexity reduction:

$$\mathrm{T_{saving}} = \frac{\mathrm{Time_{VTM}} - \mathrm{Time_{proposed}}}{\mathrm{Time_{VTM}}} \times 100\% \tag{10}$$

Rate control will invariably result in a heavy computational cost. Thus, we examine our method's convergence speed from the perspective of utilized time. Notably, our investigation confirms that each repetition only needs a small amount of processing time. To put it succinctly, the suggested approach can optimize bit allocation at low encoding complexity costs. Thus, by incorporating the more precise R-D estimation, our system can allocate bits optimally with minimal additional complexity cost.

Due to appropriate bit allocation and precise Q-λ relationship, the suggested approach can achieve 19.49% T_{saving} and -0.44% BDBR savings when compared to the VVC rate control technique. These findings offer significant proof of the suggested rate control algorithm's average efficacy in comparison to the initial RDOQ implementation in VTM. The performance of the original VTM and our recommended major mode selection are compared in this subsection. To assess the outcomes and the coding time reduction rate in relation to the anchor test findings, we employed the BDBR and T_{saving}.

Since it requires as little video coding time as possible to minimize delay time, it may profit from a considerable decrease in T_{saving}% compared to a decrease in BDBR that was modest enough to be applied to online and real-time video communication. Table 1 and Figure 2 display the test results using the suggested method. The average BDBR% was -0.44% and the average drop in T_{saving}% was 19.49%. Table 1 demonstrates that the method may, on average, save 19.49% of the encoding time at VTM 14.2 with just a small decrease in sequence test quality. To sum up, all QPs have uniform procedures, and the average time savings over VTM 14.2 is significant. The results indicate that our RC algorithm performs similarly to the rate control of the anchoring VTM 14.2 platform, with a B_{err} of 0.372%.

Because the time savings and BDBR process are directly associated with the time savings across the entire encoding process, the suggested approach enables the system to save a fair amount of time during the VTM 14.2 encoding process. For the RaceHorse sequence, the recommended method lowered the encoding time by at least 14.98%, and for the FourPeople sequence, it reduced it by better than 22.98%. The proposed method provides less T_{saving} for the fast-motion movie sequence "RaceHorse," but it performs well for videos like "FourPeople," which include a lot of smooth sections and slow motion. This demonstrates that the proposed method is efficient and universal in reducing coding complexity and may be used to any sequence. Given that it can shorten the encoding time and produce a partition prediction result that is almost identical to the original methodology, the method proposed in this work can drastically cut the encoding time while maintaining encoding quality.

We compare the proposed algorithm to other state-of-the-art works, including the Fu *et al.* (TF) algorithm in [19], Cui *et al.* (JC) algorithm in [20] and Liao *et al.* (JL) algorithm in [21], to provide an objective comparison. The VTM video coding standard and the sequences (Class A1, A2, B, C, D, and E) are used to test each method. The average time savings (T_{saving}%) average is the metric used to evaluate the algorithm's performance. The value of T_{saving}, as displayed in Figure 3, indicates the ratio of reduction in computation complexity.

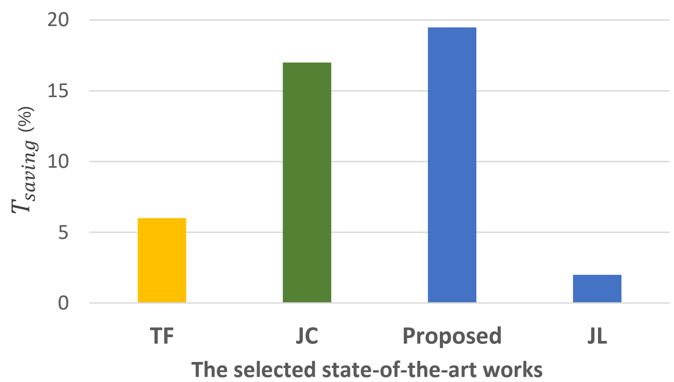

Figure 3. The comparison of the proposed algorithm experimental average results with the previous method

The suggested algorithm outperforms the current algorithms by a small margin. First, our algorithm outperformed the algorithm in [19] in terms of lowering the average coding complexity. Additionally, our algorithm's encoding time was 8.49% shorter. Next, our strategy decreased the encoding time by 1.31% in comparison to [20]. Next, our approach resulted in a 12.49% reduction in encoding time when compared to [21].

To the best of our knowledge, the low complexity rate control for VVC with hybrid Lagrange multiplier is being proposed for the first time in literature. Each unique sequence is consistent, thus there will be variations in the complexity reduction. This strategy will perform better with steady sequences and less well with rapidly changing sequences. It is expected that this method will apply these results consistently to all video encodings that comply with VTM.

The lossy encoder modules like quantization, are the source of the coding distortion, which is mostly determined by the coding settings. It seems that significant downsampling distortion implies a significant loss of high-frequency information during the resampling process. The encoder likely favors full-resolution coding in this situation. On the other hand, when the downsampling distortion is low, downsampling-based coding is probably going to perform better. Thus, the ideal coding resolution is ascertained by utilizing the downsampling distortion.

5. CONCLUSION

Experimental validation and publication of the low complexity rate control for VVC with hybrid Lagrange multiplier have been completed. The VTM 14.2 (VVC test mode) standard is used to certify real-time video communication. The optimization can reduce the coding time (t%) average by 19.49% by using the proposed method. This is a significant decrease compared to the dropping BDBR average level, which is so little as to be insignificant (-0.44%).

The test results demonstrate that the code needed for real-time video transmission may be completed in a shorter amount of time, which is pretty good. It is expected that the same outcomes would hold true for other sequences as well, opening up further application options. These specific findings offer promising methods for further research and implementation, particularly in complexity reduction video coding efforts and rate control enhancement.

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