Statistical Modeling based Fast Rate Distortion Estimation Algorithm for HEVC

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1. Introduction

Rate distortion optimization (RDO) is the basis for algorithm optimization in video coding [1], such as mode decision, rate control and etc. Minimizing the rate distortion coding cost is usually employed to determine the optimal coding parameters such as quantization level, coding mode, and etc. However, rate and distortion calculations for optimal solution decision from massive possible candidates suffer from dramatically high computation complexity. To resolve this problem, this paper proposes a fast TU level rate model with higher accuracy by fully imitating the behavior pattern hid in entropy.

We evaluate the contribution percentages of different syntax elements in entropy coding, and individually develop syntax element-wise accurate rate models to construct the whole TU level model. In addition, coefficient levels are weighted adaptively to distinguish the nonuniform contributions of different coefficients in terms of rate profiling. Moreover, position-wise parameter is defined to depict the distribution patterns for possible non-zero coefficients within one block. The final linear rate model is developed by fine-tuning the model parameters from great amounts of samples in a statistical way. Finally, the transform domain distortion model is also established to bypass the inverse quantization and inverse transform. Experimental results show that the proposed algorithm can achieve 52.68% complexity reduction with 1.67% BD-BR increase for LD configuration. , and 49.76% complexity reduction with 1.74% BD-BR increase for RA configuration, respectively.

2. Syntax Element Rate Profiling

The rate proportion of each syntax element are detailed in Figure 2 under different combinations of TU size and quantization parameter (QP). The experimental results is derived from BasketballPass sequence with Random Access (RA) configuration. In the case of TU 4x4 and 8x8, the LP syntax element accounts for a large proportion, which are 32.2% and 25.8% on average, respectively. The distribution ratio of G1 and CSF syntax elements are relative uniform for different QPs, and the SCF syntax element accounts for the largest proportion in comprehensive consideration. These statistical results will guide the following rate estimation algorithm.

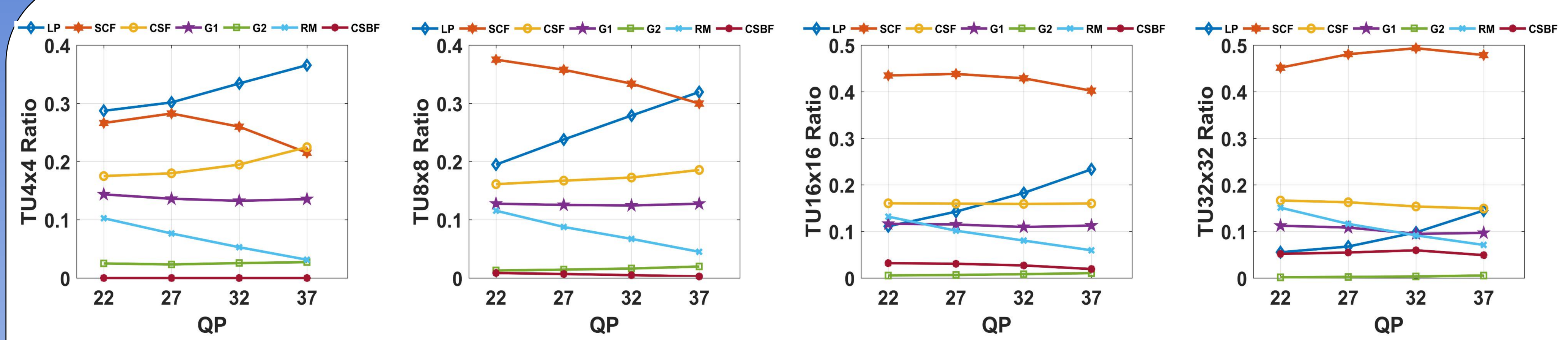

Figure 1: Rate profiling

3. Rate Estimation for Coefficient Part

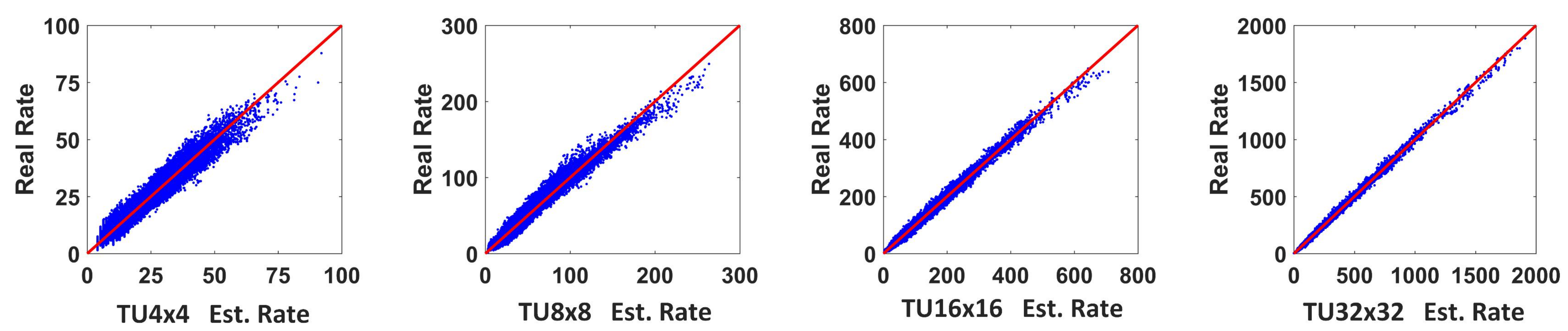

Figure 2: Relationship between Est. rate and Real Rate

The final model is shown as Equation (1).

$$R_{Est} = \theta_0 + \theta_1 \cdot \sum_{i=1}^{\frac{N^2}{16}} \sum_{j=1}^{16} \left| W_{kj} L_{ij} \right| + \theta_2 \cdot \sum_{m=1}^{\frac{N^2}{16}} (\eta_{c,m} + \eta_{z,m}) + \theta_3 \cdot \eta_b + \theta_4 \cdot \eta_n \qquad (1)$$

W_{kj} represents the coefficient weight and L_{ij} represents the quantized coefficient, $\eta_{c,m}$, $\eta_{z,m}$ represents position parameters, η_b as the last non-zero coefficients parameters, η_n as the number of non-zero coefficients

4. Proposed Distortion Estimation Algorithm

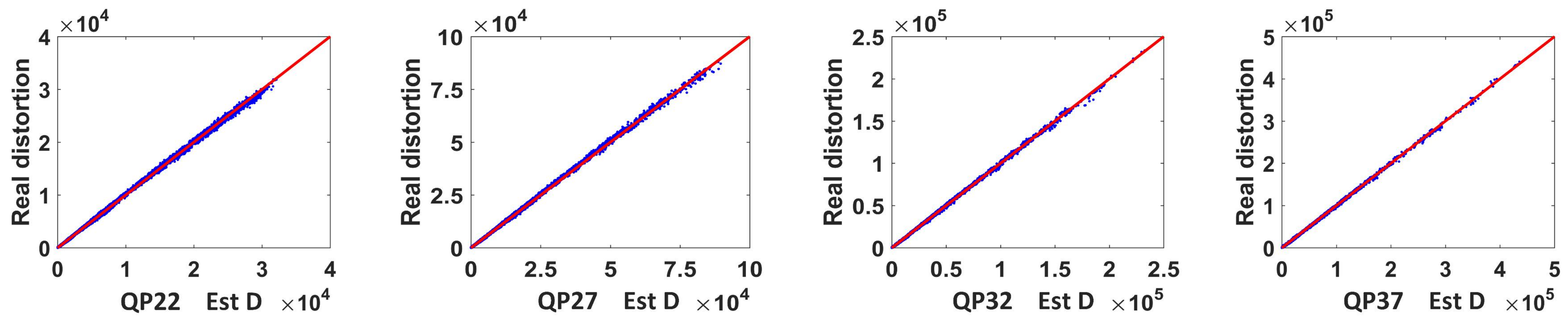

Figure 3: Relationship between Est D and Real Distortion

$$D_e = \sum_{i,j} (y\_ij \cdot S\_c - (Q\_ij \ll iQBits))^2 \qquad (2)$$

$$D_{Est} = \alpha(QP) \cdot \left(\frac{D_e}{(S_c)^2} \gg 2 \cdot shift\right) \qquad (3)$$

where α(QP) is the distortion model parameter related to QP, and shift is the number of shifted bits related to TU size. The relationship between D Est and real distortion are shown in Figure 3.

5. Rate Estimation for Header part

$$R_{skip} = \begin{cases} \alpha_0 \cdot QP + \beta_0 & Nonskip\ mode \\ \alpha_1 \cdot QP + \beta_1 & Skip\ mode \end{cases} \qquad (4)$$

when neighboring units are in non-skip mode, α0=0.01689, β0=0.1833, α1=-0.1073,β1=5.814. When neighboring units have one or two in skip mode, the rate model can be established in the same way.

$$R_{luma} = \begin{cases} \gamma_0 \cdot QP + \delta_0 & NonMPM\ mode \\ \gamma_1 \cdot QP + \delta_1 & MPM\ mode \end{cases} \qquad (5)$$

where γ0=0.04173, δ0=0.1384, γ1=-0.02682, δ1=1.578. The intra chroma pred mode is used to describe whether the best mode is same as the best luma mode or not, and the model is created similar asprev intra luma pred flag.

6. Conclusion

In this paper, a statistical modeling based fast rate distortion estimation algorithm for HEVC is proposed. For rate estimation, the model for coefficient and header parts are established based on the syntax element level statistical results, respectively. For distortion estimation, the transform domain distortion modeling is established. Experimental results show that the proposed algorithm can achieve 52.68% complexity reduction with 1.67% BD-BR increase for LD configuration, and 49.76% complexity reduction with 1.74% BD-BR increase for RA configuration, respectively.