# Rate-Distortion Optimized Multi-Stage Rate Control Algorithm for H.264/AVC Video Coding

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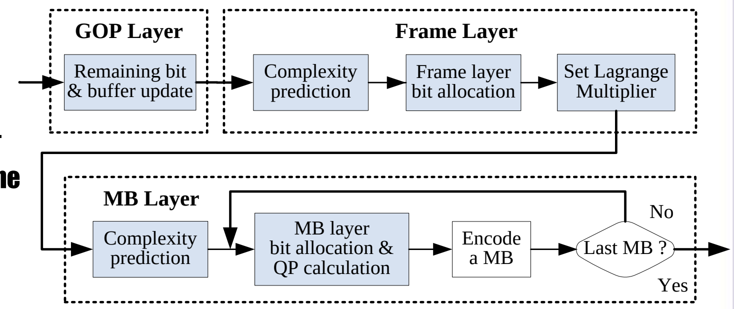
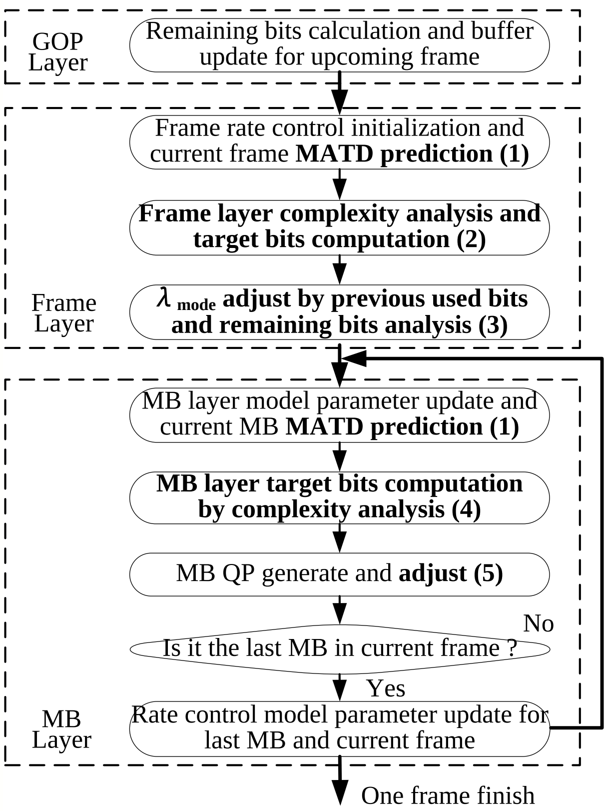
## ■ Introduction

**H.264/AVC**: the latest and most advanced video coding standard.
**Rate Control**: regulate output bit-streaming to meet bandwidth /buffer constraints and keep the coding quality.
**Target**: video applications such as videophone or video conference.
**Focus on**: bit allocation, RDO based mode decision, QP generation.




◆ Block diagram of encoding one frame with rate control

## ■ Multi-Stage Rate Control Scheme




◆ Proposed RDO based rate control scheme

### 1. Coding Complexity Estimation

**Coding complexity**: to have more precise estimation, a frequency-domain parameter, the mean-absolute-transform-difference (MATD) is introduced in this work. The 4 × 4 Hadamard transform is executed for complexity prediction. MATD is adopted to represent residual complexity instead of MAD because of its slightly better performance in the source rate model

$$\begin{cases} SATD\_4\times4=\sum_{m=1}^{4\times4}\left|T\{C_m(x,y)-P_m(x,y)\}\right| \\ MATD\_mb=\dfrac{\sum_{n=0}^{15}SATD\_4\times4_n}{16\times16}\times\eta \\ MATD\_f=\dfrac{\sum_{n=1}^{N_{mb}}MATD\_mb_n}{N_{mb}} \end{cases}$$

### 2. Frame Layer Bit Allocation

$$\begin{cases} T_j=\beta\cdot T_{rf,j}+(1-\beta)\cdot T_{buf,j} \\ T_{rf,j}=\dfrac{T_r(j)}{N_r} \\ T_{buf,j}=(u/F_r)-\gamma\cdot(B_c(j)-B_t(j)) \end{cases}$$

$$T_{rf,j}=MATD_{Ratio,j}\cdot\frac{T_r(j)}{N_r}\qquad MATD_{Ratio,j}=\frac{MATDP_j}{\sqrt{\frac{1}{j-1}\times\sum_{l=1}^{j-1}MATDA_l^2}}$$

**Frame complexity analyze**: compare current frame complexity with that of all coded frames to utilize the trend of frame layer bit usage.

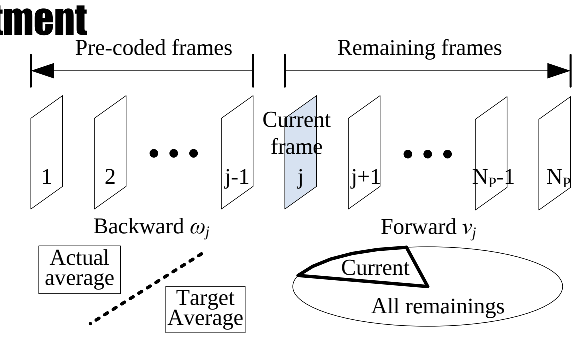
### 3. Adaptive Lagrange Multiplier Adjustment

$$\begin{cases} \min\{J_{MODE}\} \\ J_{MODE}=D+\lambda_{MODE}\cdot R \end{cases}$$

$$\lambda_{MODE}=0.85\times2^{(QP-12)/3}$$

$$\lambda_{MODE}=0.85\times f_R\times2^{(QP-12)/3}$$

**Lagrange Multiplier**: large $\lambda_{MODE}$ corresponds to higher distortion & lower bit-rate. Smaller one corresponds to lower distortion & higher bit-rate.
**Backward factor $\omega_j$**: a factor to measure the average utilized number of bits for all coded frames.
**Forward factor $v_j$**: the proportion of the bit usage of current frame among that of all not-yet-coded frames.




◆ Calculation of forward and backward adjusting factor

$$\omega_j=\frac{\frac{1}{j-1}\times(\sum_{l=1}^{j-1}B_{f,l})}{\frac{T_P}{N_P}},\qquad v_j=\frac{T_j}{\frac{T_r(j)}{N_r}}$$

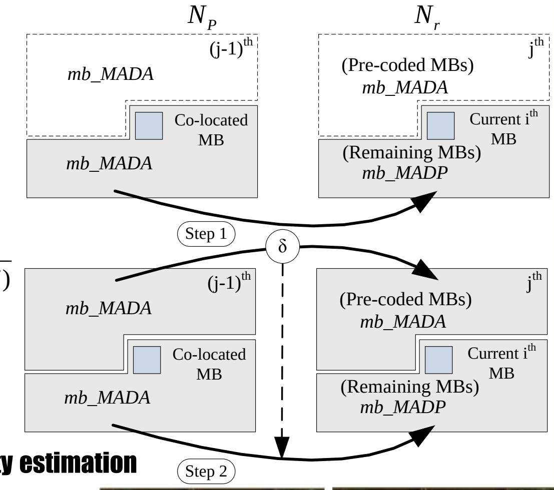
$$Bit_{Ratio,j}=\frac{\omega_j}{v_j}\quad\text{for } j>1\qquad f_R(j)=Bit_{Ratio,j}\cdot\sqrt{\frac{Bit_{Ratio,j}}{Bit_{Ratio,j-1}}}$$

### 4. MB Layer Bit Allocation

$$\delta_{i,j}=\frac{\sum_{m=1}^{i-1}(mb\_MATDA_{m,j})}{\sum_{l=1}^{i-1}(c_{i,j}\times mb\_MATDA_{l,j-1}+d_{i,j})}\qquad mb\_T_{i,j}=T_j\times\frac{mb\_MATDP_{i,j}}{mb\_MATDP_r(j)}$$

$$mb\_MATDP_r(j)=\delta_{i,j}\times\sum_{n=i}^{N_{mb}}(c_{i,j}\times mb\_MATDA_{n,j-1}+d_{i,j})$$

**Remaining MB complexity**: whole complexity information of current and previous frames is utilized to compute MB target bits.




◆ Proposed remaining MBs complexity estimation

### 5. MB Layer QP Adjustment

$$mb\_B_{i,j}=mb\_T_{i,j}-mb\_H_{i,j}$$

**If** $mb\_B_{i,j}<\dfrac{u}{F_r\cdot N_{mb}\cdot MINVALUE}\}$

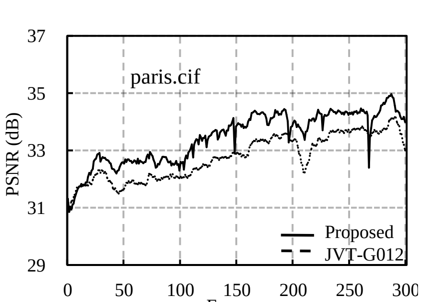
$$QP_{i,j}=QP_{i,j}+\Delta QP_{i,j}$$

$$\Delta QP_{i,j}=\begin{cases}2, & mb\_B_{i,j}<LB-5\theta \\ 1, & LB-5\theta\le mb\_B_{i,j}<LB-\theta \\ 0, & mb\_B_{i,j}\ge LB-\theta\end{cases}$$

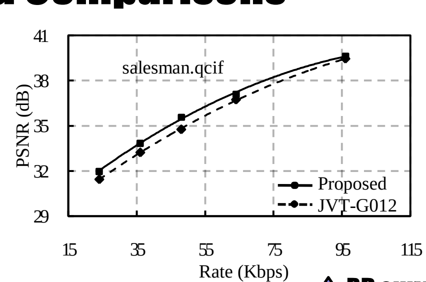
$$\theta=\frac{LB}{2}=\frac{1}{2}\times\frac{u}{F_r\cdot N_{mb}\cdot MINVALUE}$$

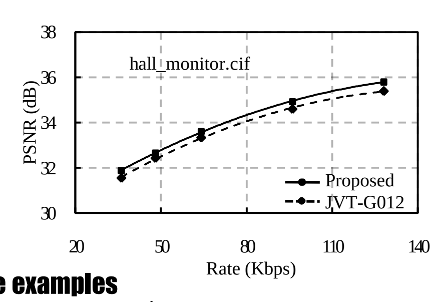
**QP Adjustment**: when $mb\_B_{ij}$ is smaller than lower bound, the computed $QP_{ij}$ will be adjusted to avoid excess bit generation.

## ■ Simulation Result and Comparisons

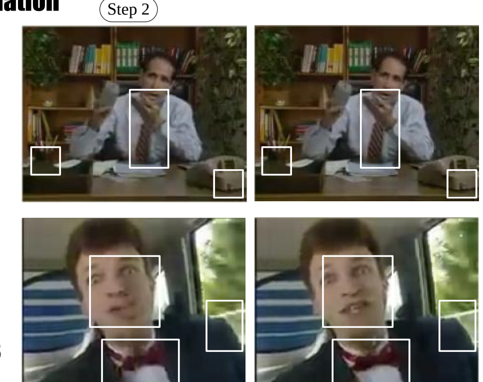



◆ PSNR examples




◆ RD curve examples



◆ Reconstructed frame examples