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# A Constrained Variable Bit Rate (CVBR) Algorithm for VVenC, an Open VVC Encoder Implementation

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## INTRODUCTION

Two basic video coding approaches in industry:
- rate control (RC): encoder control using $R_{trgt}$
- constant quality: encoder control using $QP_{seq}$

For smooth playback at restricted bandwidths, staying below a **max.** rate shall be guaranteed
- up to mid 2023, VVenC didn't enforce a $R_{max}$

## CONTRIBUTION

Rate capping extension for RC modes in VVenC
- via $R_{max} \geq 1.5 \cdot R_{trgt}$, using frame picture stats

Stats: motion info from MCTF, rate info from RC
- MCTF: motion compensated temporal filter[1]
- RC: rate estimates from fast preencoding pass
- stats are readily available → **low complexity**

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$QP_{seq}$: sequence quantization parameter, similar to CRF,  1: A. Wieckowski et al., PCS 2022.

## VVENC'S RC MODEL
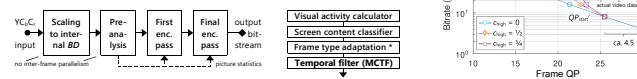


**2-step R-QP model based on 1st-pass frame data**

$$q_f'' = \left\lfloor q_f' + c_{high} \cdot \max(0; \; QP_{start} - q_f') + o_l + \tfrac{1}{2} \right\rfloor$$

with $o_l$: 2nd-pass corrective offset at temp. level $l$, $B$: set of all past frames $f$ at level $l$

$$q_f' = q_f - c_{low} \cdot \sqrt{\max\left(1; \; q_f\right)} \cdot \log_2\left(\frac{r_f''}{r_f}\right)$$

**Second-pass target rates $r_f''$ depend on RC mode**
- GOP-wise RC: each Intra period to exhibit $R_{trgt}$
  - ⓘ does not spend more rate on difficult scenes
- file based RC: entire video shall average at $R_{trgt}$
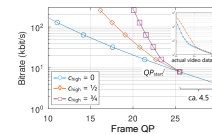  - ⓘ may spend too much rate on difficult scenes

## CVBR CODING WITH VVENC

Goal: cap at $R_i$ = rate averaged across Intra period
- ⓘ we don't know if users measure in same way

Approach: limit GOP-wise target bit count to $g_{max}$

$$g_{max} = \frac{R_{max}}{fps} \cdot \frac{G \cdot I}{1 + m_0 \cdot G} \cdot \begin{cases} 1 + m_0 & \text{for I-GOPs[2]} \\ 1 & \text{otherwise} \end{cases}$$

with $g$: GOP's bit count, $G$: GOP size, $I$: Intra-frame period

where $m_0 = r_{fo}' / g_{fo}'$: I-frame to GOP bit ratio
- $m_0 \approx 1$ on little, $\approx 1/32$ on strong motion
- I-GOPs use at most 2·rate of non-I-GOPs

**GOP-wise RC:** temporarily allow more rate
- find max. of MCTF motion errors in GOP
- save max. of last 8 GOPs and their mean
- spend via $r_f''$ more rate when max ≫ mean

**File based RC:** cap based on 1st-pass rate $r$
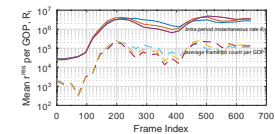- if GOP-rate is reduced, store saved bits Δ
- sum up all Δ in video, spend them evenly in all non-reduced GOPs, reduce again ↻

In both RCs, ensure $o_l$ is chosen s.t. $g \leq g_{max}$

## EVALUATION



$R_{max} \approx 2 \cdot R_{trgt}$ is good tradeoff; details at 3

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2: I-GOP: group of pictures containing Intra-frame, 3: www.ecodis.de/ratecap.htm

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Averaged Bjøntegaard delta-rate (BDR) and rate accuracy (BitErr) results, using VVenC preset *fast* with XPSNR based visual opt., commit ec61375 as reference:

**GOP-wise RC:** $R_{max} = \infty$: BDR -1.90%, BitErr 2.72%;  $R_{max} = 2R_{trgt}$: BDR -2.00%, BitErr 2.52%;  $R_{max} = 1.5R_{trgt}$: BDR -1.98%, BitErr 2.90%

**File based RC:** $R_{max} = \infty$: BDR -0.46%, BitErr 0.90%;  $R_{max} = 2R_{trgt}$: BDR 0.31%, BitErr 1.19%;  $R_{max} = 1.5R_{trgt}$: BDR **3.95%**, BitErr 2.94%