ADAPTIVE BITRATE REGULATION FOR Scalable Video Applications

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H.264/SVC and Rate Control

- **H.264 Scalable Video Coding (H.264/SVC)**
  - An extension of H.264/AVC standard
  - Provide scalability in temporal, spatial and SNR dimensions
  - Create a video bit stream that is structured in layers

- **Rate control (RC)**
  - Regulate encoding bitrates to meet network bandwidth while obtaining optimum encoding quality
  - Very crucial in video compression and communication
H.264/SVC Rate Control (RC)

- Regulate the encoding bitrate of each SVC layer to meet the network bandwidth while obtaining optimum encoding quality

Related Work
- Very few RC developed for H.264/SVC
- Most of them typically apply H.264/AVC RC approaches to each scalable coding layer individually
- Perform target bit prediction within the same encoding layer
- Inter-layer prediction has not been considered

Limitation:
- When an abrupt change happens, target bit estimation for the current frame only based on its previous frame might not be accurate and effective
- Might degrade RC performance
The proposed research

- Basic Idea
  - When an abrupt change happens, predict the current frame’s target bits from the previous layer might be more accurate as the abrupt change has already been reflected when encoding in the previous layer

- Proposed an Adaptive Inter-layer RC for H.264/SVC
  - Unique features
    - Propose Inter-layer bit estimation
    - Develop a switch model
ADAPTIVE INTER-LAYER RC – OVERALL SYSTEM STRUCTURE
ADAPTIVE INTER-LAYER RC – A & B

- A. Rate-Complexity-Quantization (R-C-Q) Model
  - R-C-Q relationship in k\textsuperscript{th} SVC layer \cite{1, 2}
  \[ R_k = \alpha_k \times e^{-\beta_k \times QP_k} \]


- B. QP Calculation for Intra-frames
  \[ QP_{intra,k} = \frac{\text{Sum}_{QP}}{N_P} - 1 - \frac{N_{IntraPeriod}}{15} \]
ADAPTIVE INTER-LAYER RC – C

C. Adopt our proposed Proportional-Integral-Differential (PID) buffer control technique\textsuperscript{[3]}

- To tune the initial frame bit target for each layer to avoid buffer overflow and/or underflow

\[
PID_{t,k} = K_p \times E_{t,k} + K_i \times \sum_{\tau=1}^{t} E_{\tau,k} + K_d \times (E_{t,k} - E_{t-1,k})
\]

with
\[
E_{t,k} = B_{T,t}^k - B_{f,t}^k
\]


- Obtain the bit increment for the current frame relative to its previous frame by:

\[
\Delta R_{k,1} = PID_{t,k} - PID_{t-1,k}
\]
D. Switched Inter-Layer Bit Estimation

- PID buffer controller:
  - Effectively predicts current frame’s target bits according to its previous frame’s info, on the same layer
  - Limitation: when abrupt change happens, it might not work good

- Solution: Inter-layer Bit Prediction
  - Predict current frame’s target bits from the previous layer

- Inter-layer bit estimation: calculate the current frame’s bit increment based on its previous layer by:

\[
\Delta R_{k, 2} = \frac{R_{t, k-1} - R_{t-1, k-1}}{R_{t-1, k-1}} \times R_{t-1, k}
\]
D. Switched Inter-Layer Bit Estimation (Cont’d)

- Inter-layer bit estimation:
  - Useful for abrupt changes of video sequence
  - Might not work efficiently when no obvious changes
- Switching Model: to predict the frame target bits either from the current layer or from the previous layer

\[
\text{if } \text{sign}(\Delta R_{k, 2}) = \text{sign}(\Delta R_{k, 1}) \text{ and } |\Delta R_{k, 2}| > |\Delta R_{k, 1}| \text{ then}
\]

\[
\Delta R_{\text{inter},k} = \Delta R_{k, 2}
\]

\[
\text{else}
\]

\[
\Delta R_{\text{inter},k} = \Delta R_{k, 1}
\]

\[
\text{endif}
\]
**ADAPTIVE INTER-LAYER RC – E & F**

- **E. Incremental QP Calculation for Inter-frames**
  - After the bit increment is obtained, calculate QP by using our previous proposed method:

  \[
  QP_{\text{Inter}, t}^k = QP_{\text{Inter}, t-1}^k - \frac{1}{R_{\text{Inter}, t-1}^k \times \beta_{\text{Inter}, k}} \times \Delta R_{\text{Inter}, k}
  \]


- **F: Encoding and Post-Encoding Process**
  - Use QP to encode the current frame
  - Do related process after encoding
## Overall Performance Comparisons for Basic Layer RC

<table>
<thead>
<tr>
<th>Seq. (CIF)</th>
<th>Alg.</th>
<th>Bit Rate (Kbps)</th>
<th>Skip Fr.</th>
<th>PSNR (dB)</th>
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PERFORMANCE COMPARISON – MULTILAYER RC

(a) Layer 0 Buffer Fullness (96k)
(b) Layer 1 Buffer Fullness (192k)
(c) Layer 2 Buffer Fullness (512K)

(d) Layer 0 PSNR (96k)
(e) Layer 1 PSNR (192k)
(f) Layer 2 PSNR (512K)

Coastguard
CONCLUSION

- Proposed an Adaptive Inter-Layer Rate Control Algorithm for H.264/SVC
  - Propose Inter-layer bit estimation
  - Develop a switch model to predict bits either from the current layer or from the previous layer
  - Increase the accuracy of bit estimation and rate control

- Experimental Results
  - Achieve accurate rate regulation
  - Maintains stable buffer fullness
  - Reduces frame skipping and PSNR fluctuation
  - Improve overall coding quality

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