Model-based Rate Allocation in Distributed Video Coding Systems

Yevgeny Priziment and David Malah

Department of Electrical Engineering
Technion IIT, Haifa 32000, Israel

IEEE 25-th Convention of Electrical and Electronics Engineers in Israel, 2008

Outline

Distributed Video Coding - Motivation

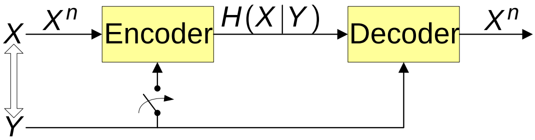
Standard Video Coders - MPEG, H.26x

- Based on hybrid of Motion Estimation and Transform Coding
- Complex encoder - due to ME
- Downlink oriented

New Video Applications - Wireless/Cellular Video, Surveillance

- Low cost $\searrow$
- Limited power $\rightarrow$ Low complexity encoder
- Limited computational resources $\nearrow$
- Limited bandwidth $\rightarrow$ coding efficiency
- Uplink oriented

Background - Source Coding with Side Information



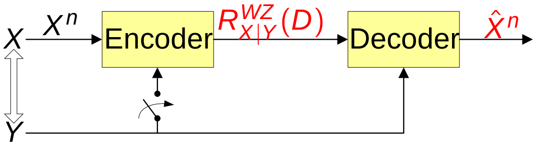
Slepian Wolf (SW) Coding - Lossless Case

- Switch open: $R^{SW}_{X|Y} = R_{X|Y} = H(X|Y)$, no rate loss

Wyner Ziv (WZ) Coding - Lossy Case

- RD function: $R^{WZ}_{X|Y}(D) \geq R_{X|Y}(D)$
- Equality holds if: $Y = X + N$, X and N independent Gaussian sources, MSE distortion
- Practical WZ coding: Quantization followed by SW coding

Background - Source Coding with Side Information



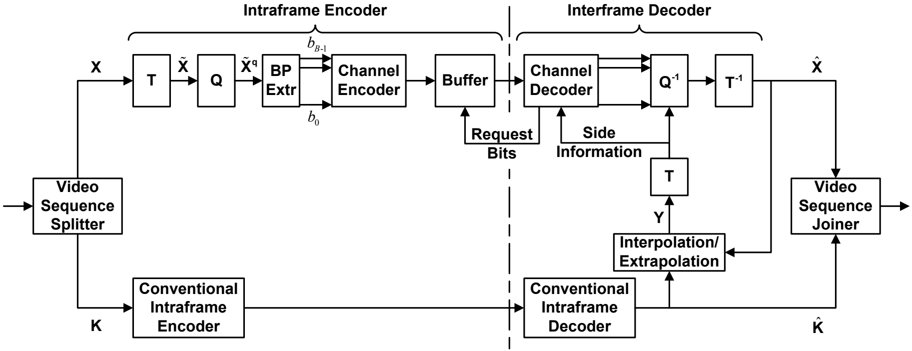
Slepian Wolf (SW) Coding - Lossless Case

- Switch open: $R^{SW}_{X|Y} = R_{X|Y} = H(X|Y)$, no rate loss

Wyner Ziv (WZ) Coding - Lossy Case

- RD function: $R^{WZ}_{X|Y}(D) \geq R_{X|Y}(D)$
- Equality holds if: $Y = X + N$, X and N independent Gaussian sources, MSE distortion
- Practical WZ coding: Quantization followed by SW coding

DVC System



Intraframe Encoder
Interframe Decoder
X
T
X̃
Q
X̃q
BP
Extr
b_{B-1}
b_0
Channel
Encoder
Buffer
Channel
Decoder
Q-1
T-1
X̂
Request
Bits
Side
Information
T
Y
Video
Sequence
Splitter
Interpolation/
Extrapolation
Video
Sequence
Joiner
Conventional
Intraframe
Encoder
K
Conventional
Intraframe
Decoder
K̂

Need for Feedback Suppression

Feedback Channel

- Incurs delay $\longrightarrow$ Unsuitable for real-time applications
- Not available in some apps. (e.g. storage)

Related Work [Morbee 06, 08], [Brites 07]

- Studied performance of a system with feedback offline or evaluated $H(X|Y)$ at bitplane level.
- Rate estimation is based on the quantized data

Feedback Suppression

- Proposed approach: Encoder–side rate control based on a rate distortion model

Rate Distortion Model

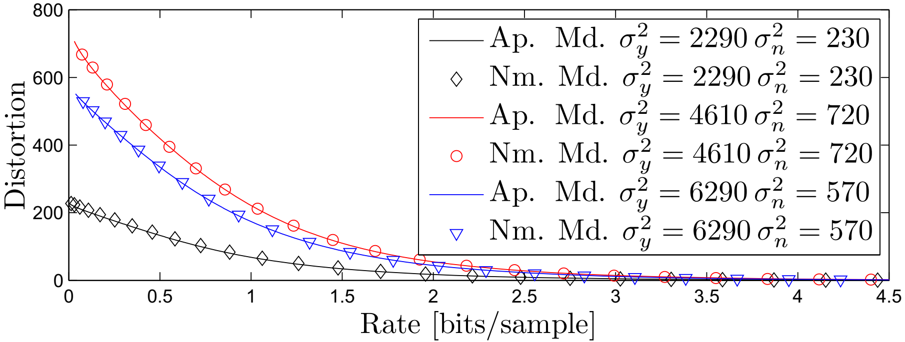
WZ Coding - Laplacian Sources [V. Sheinin 06]

- $X = Y + N$, $Y \sim Laplace(\mu_y, \sigma_y^2)$ and $N \sim Laplace(\mu_n, \sigma_n^2)$ i.i.d., N independent of Y
- Infinite Uniform Scalar Quantizer - $IUSQ(\Delta, \varepsilon)$
- RD characterization assuming perfect SW coding $H(X|Y)$
- The RD model is given in integral form expressions

Approximation RD Model

- $R(\Delta) = \exp\left[a_r \exp(-(\Delta/b_r)^{\gamma_r}) + m_r\Delta + n_r\right]$
- $D(\Delta) = \exp\left[a_d \exp(-(\Delta/b_d)^{\gamma_d}) + n_d\right]$
- $\{a_r, b_r, \gamma_r, m_r, n_r\}$ and $\{a_d, b_d, \gamma_d, n_d\}$ are evaluated offline for a set of σ_y^2, σ_n^2 and ε

Approximation RD Model vs. Numerical Model

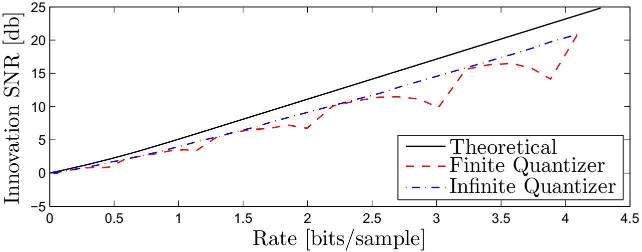


Practical WZ Encoder Design

Remaining Questions

Once obtaining Δ that satisfies the RD constraints:

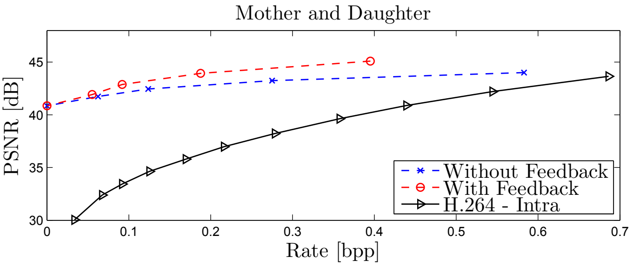
- What is the *number of IUSQ bin labels?* (Nested Quantiztion)
- What should be the *rate of each bitplane?*
- Both questions can be answered by evaluating the RD function



Applications of RD Model in DVC

DVC Encoder–Side Rate Control

- Feedback suppression - evaluate RD for the whole frame
- Use frame difference to estimate 'noise' statistics (applicable only to low motion sequences)

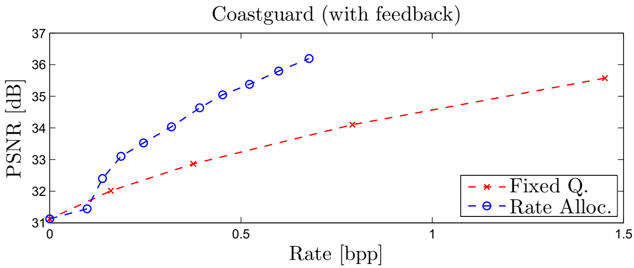


Rate Allocation

- Split WZ frames into disjoint slices, evaluate RD for each slice
- Applicable to systems with and without feedback

$$\min_{(q_0,\ldots,q_{S-1})} \sum_{s=0}^{S-1} D_s, \qquad \text{s.t.} \sum_{s=0}^{S-1} R_s(D_s) \leq R_{max}$$

$$q_i \in \{\Delta_0, \ldots, \Delta_{m-1}\}$$



Summary

- Approximation to the WZ rate distortion model for Laplacian sources
- Feedback suppression using model based encoder rate control
- Quality enhancement by applying rate allocation to disjoint slices in systems with and without feedback
- Outlook
  - Generalizing the feedback suppression framework for sequences with medium-high motion activity
  - Testing the proposed system on more sequences