ECE 634: Digital Video Systems
Video encoding: 3/7/17

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Encoding strategies

Encoding strategies

- Frame-type selection
- Motion estimation
- Mode selection
- Quantization
- In-loop filtering
- Pre-loop filtering

Operational control of a video coder

- Typical video sequences contain varying content and motion
- Different content is compressed well with different techniques
- Encoders should match coding techniques to content

- Coding parameters
  - Macroblock type (coding mode)
  - Motion vectors
  - Quantizer step size
- Each leads to different rate and distortion

Coding Mode Selection

- Coding modes:
  - Intra vs. inter, QP to use, for each MB, each leading to different rate
- Rate-distortion optimized selection, given target rate:
  - Minimize the distortion, subject to the target rate constraint

$$\text{minimize} \quad \sum_n D_n(m_n),$$

$$\text{subject to} \quad \sum_n R_n(m_k, \forall k) \le R_d.$$

$$\text{minimize} \quad J(m_n, \forall n) = \sum_n D_n(m_n) + \lambda \sum_n R_n(m_k, \forall k)$$

Simplified version $$J_n(m_n) = D_n(m_n) + \lambda R_n(m_n).$$

The optimal mode is chosen by coding the block with all candidates modes and taking the mode that yields the least cost.

Note that one can think of each candidate MV (and reference frame) as a possible mode, and determine the optimal MV (and reference frame) using this frame work --- Rate-distortion optimized motion estimation.

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Rate Control: Problem definition

- The coding method necessarily yields variable bit rate
  - More active periods use more bits – prediction is less accurate
  - An I-frame uses many more bits than a P-frame or B-frame
  - Variable length coding
- Video is almost always either:
  - Sent over a constant bit rate (CBR) channel, where the rate when averaged over a short period should be constant
  - Sent over a variable bit-rate (VBR) channel that does NOT have the same variability as the bitstream
- The bit-rate fluctuation can be smoothed by a buffer

Rate control: Decoder buffer

- Once the decoder starts to decode, it must decode one frame every frame period – otherwise the video will stall
- Pre-load decoder buffer with L frames of video
- Ensure decoder buffer never underflows

$$(N+L)R - \sum_{j=0}^{N} E_j \geq 0$$

- For CBR channel: Encoder buffer should never overflow

$$\sum_{j=0}^{N} E_j - NR \leq B_{\max}^{e}$$

Rate Control: Problem solution

- Adjust bit-rate of compressed video to avoid encoder buffer overflow
- Step 1) Determine the target rate at the frame or GOB level, based on the current buffer fullness
- Step 2) Satisfy the target rate by varying frame rate (skip frames when necessary) and QP
  - Determination of QP requires an accurate model relating rate with Q (quantization stepsize)
    - General model: R ~ A/Q + B/Q^2

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Loop Filtering

- Errors in previously reconstructed frames (mainly blocking artifacts) accumulate over time with motion compensated temporal prediction
  - Reduce prediction accuracy
  - Increase bit rate for coding new frames
- Loop filtering:
  - Filter the reference frame before using it for prediction
  - A side-effect of non-integer motion compensation
  - Explicit deblocking filtering: removing blocking artifacts after decoding each frame
- Loop filtering can significantly improve coding efficiency, particularly at low bit-rates