Review of Last Class

- Multiple Description Coding
  - Conceptual comparison with layered coding
  - MDC via temporal interleaving
  - MDC via multiple description scalar quantizer
  - MDC via pairwise correlating transform

- Today:
  - Performance and Summary of MDC
  - Issues on error resilient communications

Recall: Tradeoffs in Designing MDC

- Side coder (1 good ch.)
  - Rate R1 & R2
  - Reconstruction error/distortion D1 & D2

- Central coder (2 good ch.)
  - Rate R12 = R1 + R2
  - Reconstruction error/distortion D12
    - Equiv. SDC rate corresponding to $D_{12} \Rightarrow R'(D_{12})$
    - Redundancy rate $\rho = R_{12} - R'(D_{12})$

- Given R1 & R2, find relations among $R'(D_{12})$, $D_{12}$ and $D_1$
  - Vaishampayan '93

- Given $D_{12}$ hence $R'(D_{12})$, find relations ofrho vs. $D_1$
  - Wang et al. '01
  - Redundancy-rate vs. distortion tradeoff $\rho(D_1; D_{12})$
**MDC Using Pairwise Correlating Transform (PCT)**

- **Basic idea**
  - Generate two descriptions that are uncorrelated within same description but pairwise correlated across different descriptions
  - Introduce correlation to two quantized uncorrelated r.v.
  - Encode two correlated r.v. from PCT output
  - Perform inverse PCT when both r.v. are received
  - Estimate the missing r.v. then perform inverse PCT if only one is rec’d
    * e.g. linear estimator

- **Redundancy-Rate Distortion (RRD)**
  - Redundancy rate $\rho(D_1; D_{12})$
    - Given tax-ch. distortion $D_{12}$ (or the 2-ch. rate), how many bits of redundancy per r.v. to achieve a desired tax-ch. distortion $D_1$ are needed?
  - $D_1$ from $(\sigma^2 + D_{12})/2$ to $D_{12}$ where $\sigma$ is source r.v.’s variance

**Issues in Designing PCT-based MDC**

- **Optimal PCT**
  - Integer-to-integer PCT on quantized coefficient pairs
  - Optimal redundancy allocation among different pairs
  - Optimal pairing strategy under fine vs. coarse quantization

**Optimal PCT & Implementation Issues**

- **Optimal PCT**
  - $[C\ D]' = T [A\ B]$  
    * Equiv. to change basis to $v_1$ and $v_2$ where $T^{-1}(v_i) = [v_1\ v_2]$  
    - Find optimum transf. to minimize $D_1$ for a given redundancy rho
    - Opt. transf. formed by equal-length basis vector rotated away with same angle to achieve desired redundancy  
      (see Wang’01 Sec.IV)

- **Integer-to-integer PCT**
  - Use existing transf. coding framework to control quantization errors
    * quantize before PCT
  - Integer $\rightarrow$ PCT $\rightarrow$ still integer?  
    (see Wang’01 Sec.IIIB)
Optimal Redundancy Allocation and Pairing

- **Optimal redundancy allocation among many r.v. pairs**
  - Similar Lagrangian approach to previous optimal bit-allocation problem using R-D fane.
  - **constant slope method to achieve same marginal gains**
  - For optimal redundancy allocation, MDC for each coeff. pair should operate at the same slope on its RRD curve
  (See Wang’01 Sec.II & Sec.V-A)

- **Optimal pairing strategy**
  - Under fine quantization: prefer pairing kth largest with (L-k)th
  - No need to pair and add redundancy to small r.v. with magnitude comparable with quantization step size
  (See Wang’01 Sec.V-B&C)

PCT-based JPEG-like MDC Coder

- **Coder block diagram**
  [See Wang’01 Fig.1(b)]

- **Performance reported in Wang’01 Sec.VI**
  - Single-ch. PSNR vs. redundancy introduced
    - *PCT is better than MDSQ at low redundancy range*
    - *MDSQ perform better in high redundancy (high PSNR) range*
  - Image examples: Wang’01 Fig.12

Error Resilient Communications

*Fig. 11.* RRD performance of different coders for image horse. $R^* = 0.070$ bpp, $D_1 = 32.51$ dB.
Types & Consequences of Transmission Errors

- **Types of errors**
  - Error in the values of individual bits
  - Loss of bits (e.g. packet loss)

- **Potential cause of error vulnerability for multimedia stream**
  - VLC (variable length coding)
  - Predictive coding

- **Consequences of errors**
  - Affect structure info. (headers, etc.) and content info. (coeff., MV, etc.)
  - Error could propagate

Source & Channel Coding: Separately or Jointly?

- **Recall: block diagram of typical transmission process**
  - Source coding => channel coding => multiplex/modulation => Channel

- **Shannon’s separation principle**
  - Designing source and channel coders separately then combining together can achieve as good performance as the best design
    - Only true under assumptions of arbitrarily long block length (for source and channel codes), and arbitrarily high computation resource and delay
    - Not hold theoretically for broadcast and multicast channels

- **Feasible and efficient MM transmission prefers joint source and channel methods**
  - Consider error resilience in source codec design
    - Possibly adding a controlled amount redundancy in source codec
  - Several layers of protections

Video Applications Classified by Comm. Req.

- **Interactive 2-way communications**
  - Require low-latency low-jitter

- **One-way video streaming**
  - Play-while-downloading
  - May allow a non-trivial play-out delay
    - Buffering some data beforehand to give room for combating jitter
  - Unicast, Multicast, Broadcast

- **One-way video downloading**
  - Download-then-play

Types of Channels/Networks

- **Public Switched Telephone Networks (PSTN)**
  - Plain Old Telephone System (POTS) – up to 56Kbps
  - DSL – up to 6Mbps

- **Integrated Service Digital Network (ISDN) & Broadband ISDN**
  - px64 Kbps

- **Wireless**
  - Cellular networks and wireless data network
  - Wireless LAN
  - Broadband wireless IP networks

- **Broadcast channels**
  - Terrestrial, cable, satellite
### Transport-level Error Control

- **Provide basic QoS level**
  - Additional error control in source codec will improve upon this
- **Basic approaches**
  - Forward error correction via ECC
    - e.g., for H.261 video conf. over ISDN, use BCH(511,493) with 18-bit redundancy to correct 1-bit error and detect 2-bit errors in each frame of 512 bits
  - Error-resilient packetization and multiplexing
    - interleaved packetization
    - Repeat necessary headers in packets so that each is self-decodable
    - for predictive coding, pack mutually dependent data together
  - Delay-constrained retransmission
    - Require feedback ch. available
    - For non-real-time app. or retrans. delay is within tolerable range
    - e.g., ARQ – automated repeat request
  - Unequal error protection

### Error Resilient Encoding of MM Source

- **Purpose**
  - May add controlled redundancy hence less efficient than codec optimized for efficient coding rate
  - Under targeted channel conditions
    - Achieve best decoded quality for a given amount of redundancy, or minimize incurred redundancy while maintaining a prescribed quality
    - Prevent excess error propagation & facilitate concealment
- **Types of approaches**
  - Error isolation
  - Robust entropy encoding
    - Prevent excess error propagation & facilitate concealment
  - Error resilient prediction
    - Layered coding with unequal error protection
    - Multiple description coding
  - Other joint-source-and-channel approaches —> next time

### Error Isolation

- Insert resynchronization markers
  - Markers need to be relatively long to be easily distinguished from all other valid codewords and their small perturbed versions
  - Retransmit necessary header info. after markers to help resume decoding
  - Restrict predictive coding not to across markers
  - Tradeoff between error isolation abilities and overheads
- **Data Partitioning**
  - Partition data between two synch markers to finer logic units with secondary shorter markers
    - E.g., put MB headers, MVs, DCT coeff. of a GOB/slice in separate logic units
  - Clarify: “data partitioning” for layered coding vs. error isolation

### Error-Resilient Prediction

- **Insert Intra-Blocks**
  - Inserting an entire intra frame could be expensive in terms of bit rate
  - Inserting intra-block is more efficient and flexible
  - How many to add?
  - Where to add?
    - Heuristic choices (like random placement and high-activity-area placement) are simple and perform well in general
    - When using R-D approach to determine MB’s coding type, take into account situations that reference maybe be lost
- **Independent Segment Prediction**
  - Split data into segments and perform prediction only within segments
    - E.g., temporal video redundancy coding in H.263 (last MDC lecture)
Robust Entropy Encoding

- Reversible VLC
- Error-resilient entropy coding (EREC)
- Fixed-length coding
  - VLCs: fixed-length input → variable-length codewords
  - FLCs: variable-length input → fixed-length codewords

Reversible Variable Length Codes (RVLC)

- Built-in error detection capabilities of VLCs
  - A damaged bitstream is not necessarily decodable
  - But error could affect decoding of future codewords
- Reversible VLC
  - Prefix property (same as regular VLC) & suffix property
    ⇒ two-way decodability
  - Help to narrow down the undecodable data

An Example of RVLC

- Build based on an optimal regular VLC
- Extend codeword’s suffix to achieve backward decodability
  - Prefix in reversed VLC code is the suffix in non-reversed codeword
  - Code for “C” is extended one more bit to satisfy suffix condition
  - Reassign codes according to prob.

Questions for Today

- Is RVLC necessarily lead to reduction in coding efficiency?
  - Give specific examples to demonstrate your answer
Summary

- MDC via pairwise correlating transform
  - Performance
- Error resilient communications
  - Causes and consequences of errors in MM comm.
  - Transport-level error control tools
  - Error resilient source coding

- The week after spring break:
  - More on joint source-channel approaches for MM comm.
  - (Yefeng’s survey) Decoder-side error concealment & Encoder-decoder interactive error recovery
  - (Charles’ survey) MM over DSL

Suggested Reading

- Error resilient coding
  - Chapt. 8 of Sun-Reibman’s book
  - Chapt.14 of Wang’s video textbook
  - Wang et al. survey paper in IEEE Sig. Proc. Magazine 7/00