Subband Coding Techniques

- General coding approach
  - Allocate different bits for coeff. in different frequency bands
  - Encode different bands separately
  - Example: DCT-based JPEG and early wavelet coding

- Some difference between subband coding and early wavelet coding ~ Choices of filters
  - Subband filters aims at (approx.) non-overlapping freq. response
  - Wavelet filters exhibit strong local support, thus preserve local information

- Shortcomings of subband coding
  - Difficult to determine optimal bit allocation for low bit rate applications
  - Not easy to accommodate different bit rates with a single code stream
  - Difficult to encode at an exact target rate

Embedded Zero-Tree Wavelet Coding (EZW)

- “Modern” lossy wavelet coding exploits multi-resolution and self-similar nature of wavelet decomposition
  - Energy is compacted into a small number of coeff.
  - Significant coeff. tend to cluster at the same spatial location in each frequency subband

- Two set of info. to code:
  - Where are the significant coefficients?
  - What values are the significant coefficients?

Key Concepts in EZW

- Parent-children relation among coeff.
  - Each parent coeff at level k spatially correlates with 4 coeff at level (k-1) of same orientation
  - A coeff at lowest band correlates with 3 coeff.

- Coding significance map via zero-tree
  - Encode only high energy coefficients
    - Need to send location info.
    - Large overhead
  - Encode “insignificance map” w/ zero-trees

- Successive approximation quantization
  - Send most-significant-bits first and gradually refine coeff. value
  - “Embedded” nature of coded bit-stream
    - Get higher fidelity image by adding extra refining bits
**EZW Algorithm and Example**

- **Initial threshold** ~ $2^\lfloor \log_2 x_{max} \rfloor$
  - Put all coeff. in dominant list
- **Dominant Pass** ("zig-zag" across bands)
  - Assign symbol to each coeff. and entropy encode symbols
    - $p$ – positive significance
    - $n$ – negative significance
    - $z$ – isolated zero
    - $ztr$ – zero-tree root
  - Significant coeff. move to subordinate list
    - put zero in dominant list
- **Subordinate Pass**
  - Output one bit for subordinate list
    - According to position in up/down half of quantization interval
  - Repeat with half threshold
    - Until bit budget achieved

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**Beyond EZW**

- **Cons of EZW**
  - Poor error resilience
  - Difficult for selective spatial decoding
- **SPIHT (Set Partitioning in Hierarchical Trees)**
  - Further improvement over EZW to remove redundancy
- **EBCOT (Embedded Block Coding with Optimal Truncation)**
  - Used in JPEG 2000
  - Address the shortcomings of EZW (random access, error resilience, …)
  - Embedded wavelet coding in each block + bit-allocations among blocks
**JPEG 2000 Image Compression Standard**

**JPEG 2000: A Wavelet-Based New Standard**

- **Targets and features**
  - Excellent low bit rate performance without sacrifice performance at higher bit rate
  - Progressive decoding to allow from lossy to lossless
  - Region-of-interest (ROI) coding
  - Error resilience

- **For details**
  - JPEG2000 Tutorial by Skrodras @ IEEE Sig. Proc Magazine 9/2001
  - Taubman’s book on JPEG 2000 (on library reserve)
  - Links and tutorials @ http://www.jpeg.org/JPEG2000.htm

**Examples**

JPEG2K vs. JPEG

Fig. 20: Reconstructed images compressed at 0.25 bpp by means of (a) JPEG and (b) JPEG2000.
**DCT vs. Wavelet: Which is Better?**

- **3dB improvement?**
  - Wavelet compression was claimed to have 3dB improvement over DCT-based compression
  - Comparison is done on JPEG Baseline

- **Improvement not all due to transforms**
  - Main contribution from better rate allocation, advanced entropy coding, & smarter redundancy reduction via zero-tree
  - DCT coder can be improved to decrease the gap


**Summary of Today’s Lecture**

- **Wavelet-based coding**
  - Exploring tree-based structure in Wavelet coefficients: EZW
  - JPEG 2000

- **Readings on Wavelet**
  - Gonzalez book: 8.5.3, 8.6.2
  - “A Tutorial on Modern Lossy Wavelet Image Compression” by Usevitch @ IEEE Sig. Proc Magazine 9/2001