In Introduction to Data Compression

History

• Embedded Block Coding with Optimized Truncation (EBCOT)
  – Taubman – journal paper 2000
  – Algorithm goes back to 1998 or maybe earlier
  – Basis of JPEG 2000
• Embedded
  – Prefixes of the encoded bit stream are legal encodings at lower fidelity, like SPIHT and GTW
• Block coding
  – Entropy coding of blocks of bit planes, not block transform coding like JPEG.

Features at a High Level

• SNR scalability (Signal to Noise Ratio)
  – Embedded code - The compressed bit stream can be truncated to yield a smaller compressed image at lower fidelity
  – Layered code – The bit stream can be partitioned into a base layer and enhancement layers. Each enhancement layer improves the fidelity of the image
• Resolution scalability
  – The lowest subband can be transmitted first yielding a smaller image at high fidelity.
  – Successive subbands can be transmitted to yield larger and larger images

Block Diagram of Encoder

Extreme Case is Normal

Layering
Resolution Ordering

Block Coding
- Assume we are in block k, and c(i,j) is a coefficient in block k.
- Divide c(i,j) into its sign s(i,j) and m(i,j) its magnitude.
- Quantize to \( v(i,j) = \left[\frac{m(i,j)}{q_k}\right] \) where \( q_k \) is the quantization step for block k.
- Example: \( c(i,j) = -10, q_k = 3. \)
  \[ s(i,j) = 0 \]
  \[ v(i,j) = 3 \]

Bit Planes of Normalized Quantized Coefficients

Bit-Plane Coding of Blocks
- Sub-block significance coding
  - Some sub-blocks are declared insignificant
  - Significant sub-blocks must be coded
- Contexts are defined based on the previous bit-plane significance.
  - Zero coding (ZC) – 8 contexts
  - Run length coding (RLC) – 1 context
  - Sign coding (SC) – 5 contexts
  - Magnitude refinement coding (MR) – 3 contexts
- Code block in raster order using arithmetic coding

Sub-Block Significance Coding
- Quad-tree organized group testing
- Block divided into 16x16 sub-blocks
- Identify in few bits the sub-blocks that are significant

Quad-Tree Subdivision
Quad-Tree Subdivision

Quad-Tree Subdivision Coding

ZC – Zero Coding

ZC Contexts

Examples
**RLC – Run Length Coding**

- Looks for runs of 4 that are likely to be insignificant
- If all insignificant then code as a single symbol
- Main purpose – to lighten the load on the arithmetic coder.

**SC – Sign Coding**

- $h_s = 0$ if horizontal neighbors are both insignificant or of opposite sign
- $h_s = 1$ if at least one horizontal neighbor is positive
- $h_s = -1$ if at least one horizontal neighbor is negative
- $v_s = 1$ if at least one vertical neighbor is positive
- $v_s = -1$ if at least one vertical neighbor is negative

**MR – Magnitude Refinement**

- This is the refinement pass.
- Define $t = 0$ if first refinement bit, $t = 1$ otherwise.

**Bit Allocation**

- How do we truncate the encoded blocks to achieve a desired bit rate and get maximum fidelity

**Basic Set Up**

- Encoded block $k$ can be truncated to $n_k$ bits.
- Total Bit Rate $\sum n_k$
- Distortion attributable to block $k$ is $D^k = w_k^2 \sum (c^k(i,j) - \hat{c}(i,j))^2$
  where $w_k$ is the “weight” of the basis vectors for block $k$ and $c^k(i,j)$ is the recovered coefficients from $n_k$ bits of block $k$.
Facts about Bit Allocation

- It is an NP-hard problem generally
- There are fast approximate algorithms that work well in practice
  - Lagrange multiplier method
  - Multiple choice knapsack method

Rate-Distortion Curve

- Rate-distortion curve
- Truncation points
- Encoded block

Picture of Bit Allocation

- Pick one point from each curve so that the sum of the x values is bounded by R and the sum of the y values is minimized.
- Good approximate algorithms exist because the curves are almost convex.

Notes on EBCOT

- EBCOT is quite complicated with many features.
- JPEG 2000 based on EBCOT but differs to improve compression and decompression time.
- EBCOT has
  - resolution scalability
  - SNR scalability
  - quantization
  - bit allocation
  - arithmetic coding with context and adaptivity
  - group testing (quad trees)
  - sign and refinement bit contexts
  - lots of engineering

Notes on Wavelet Compression

- Wavelets appear to be excellent for image compression
  - No blocking artifacts
  - Wavelet coding techniques abound and are very effective
- Some of the wavelet coding techniques can apply to block transforms.
- Newest generation of image compressor use wavelets, JPEG 2000.