**UWIC**

- A simple image coder based on
  - Bit-plane coding
  - Significance pass
  - Refinement pass
  - Arithmetic coding
  - Careful selection of contexts based on statistical studies
- Implemented by undergraduates Amada Askew and Dane Barney in Summer 2003.

**Arithmetic Coding in UWIC**

- Performed on each individual bit plane.
  - Alphabet is $\sum = \{0,1\}$
- Uses integer implementation with 32-bit integers. (Initialize $L = 0$, $R = 2^{32}-1$)
- Uses scaling and adaptation.
- Uses contexts based on statistical studies.

**Wavelet Transform**

- Standard Daubechies 9/7 Filters

**Original Barbara Image**
Subtract Ave of Low Res Subband

- Low-resolution subband
- Detail subbands
- Reduces overall energy of image

Divide into Bit-Planes

- Coefficients
- Sign Plane
- Bit-Planes

Coding the Bit-Planes

- Code most significant bit-planes first
- Significance pass for a bit-plane
  - First code those coefficients that were insignificant in the previous bit-plane.
  - If a coefficient becomes significant then code its sign.
- Refinement pass for a bit-plane
  - Code the refinement bit for each coefficient that is significant in a previous bit-plane

Contexts (per bit plane)

- Significance pass contexts:
  - Contexts based on
    - Subband level
    - Number of significant neighbors
    - Sign context
  - Refinement contexts
    - 1st refinement bit is always 1 so no context needed
    - 2nd refinement bit has a context
    - All other refinement bits have a context
  - Context Principles
    - Bits in a given context have a probability distribution
    - Bits in different contexts have different probability distributions

Subband Level

- Image is divided into subbands until LL band (subband level 0) is less than 16x16
- Barbara image has 7 subband levels

Statistics for Subband Levels

<table>
<thead>
<tr>
<th>Subband Level</th>
<th># significant</th>
<th># insignificant</th>
<th>% significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>144</td>
<td>36</td>
<td>28.3%</td>
</tr>
<tr>
<td>1</td>
<td>272</td>
<td>1046</td>
<td>20.6%</td>
</tr>
<tr>
<td>2</td>
<td>848</td>
<td>4592</td>
<td>15.6%</td>
</tr>
<tr>
<td>3</td>
<td>3134</td>
<td>23568</td>
<td>11.7%</td>
</tr>
<tr>
<td>4</td>
<td>12268</td>
<td>113886</td>
<td>9.7%</td>
</tr>
<tr>
<td>5</td>
<td>48282</td>
<td>504633</td>
<td>8.7%</td>
</tr>
<tr>
<td>6</td>
<td>190003</td>
<td>2262904</td>
<td>7.8%</td>
</tr>
</tbody>
</table>
Significant Neighbor Metric

- Count # of significant neighbors
  - children count for at most 1
  - 0, 1, 2, 3+

Number of Significant Neighbors

<table>
<thead>
<tr>
<th>Barbara (8bpp)</th>
<th>Significant neighbors</th>
<th># significant</th>
<th># insignificant</th>
<th>% significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4849</td>
<td>2252468</td>
<td></td>
<td>.2%</td>
</tr>
<tr>
<td>1</td>
<td>13219</td>
<td>2106866</td>
<td></td>
<td>5.9%</td>
</tr>
<tr>
<td>2</td>
<td>22276</td>
<td>104252</td>
<td></td>
<td>17.6%</td>
</tr>
<tr>
<td>3</td>
<td>30206</td>
<td>78899</td>
<td></td>
<td>27.7%</td>
</tr>
<tr>
<td>4</td>
<td>33244</td>
<td>55841</td>
<td></td>
<td>37.3%</td>
</tr>
<tr>
<td>5</td>
<td>27354</td>
<td>39189</td>
<td></td>
<td>41.1%</td>
</tr>
<tr>
<td>6</td>
<td>36482</td>
<td>44225</td>
<td></td>
<td>45.2%</td>
</tr>
<tr>
<td>7</td>
<td>87566</td>
<td>91760</td>
<td></td>
<td>48.8%</td>
</tr>
</tbody>
</table>

Refinement Bit Context Statistics

Barbara (8bpp)

<table>
<thead>
<tr>
<th>0’s</th>
<th>1’s</th>
<th>% 0’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>128,145</td>
<td>130,100</td>
<td>49.6%</td>
</tr>
</tbody>
</table>

- Barbara at 2bpp: 2nd Refinement bit % 0’s = 65.8%

Context Details

- Significance pass contexts per bit-plane:
  - For Barbara: contexts for sig neighbor counts of 0 - 3 and subband levels of 0 - 4 * 4^7 = 28 contexts
  - Index of a context:
    - Max neighbors * subband level + num sig neighbors
    - Example num sig neighbors = 5, subband level = 3, index = 4 * 3 + 5 = 17
  - Sign context
    - 1 contexts
  - 2 Refinement contexts
    - 1st refinement bit is always 1 not transmitted
    - 2nd refinement bit has a context
    - All other refinement bits have a context
  - Number of contexts per bit-plane for Barbara = 28 + 1 + 2 = 31

Max Heap

- Used in significance pass to decide which coefficient to code next
  - Goal code coefficients most likely to become significant
- All non-empty contexts are kept in a max heap
- Priority is determined by:
  - # sig coefficients coded / total coefficients coded

Reconstruction of Coefficients

- Coefficients are decoded to a certain number of bit planes
  - 101110XXXXX What should X’s be?
  - 101110000... < 101110000X < 101110111...
  - 101110100000 is half-way
- Handled the same as SPIHT and GTW
  - if coefficient is still insignificant, do no interpolation
  - if newly significant, add on .38 to scale
  - if significant, add on .5 to scale

\[ |A| = k \]

\[ \frac{.38}{A000...} + \frac{.5}{A01100} + \frac{.5}{A100...} + \frac{.5}{A111...} \]
Original Barbara Image

Barbara at .5 bpp (PSNR = 31.68)

Barbara at .25 bpp (PSNR = 27.75)

Barbara at .1 bpp (PSNR = 24.53)

Results

Compression of Barbara

Results

Compression of Lena
Results

Compression of RoughWall

UWIC Notes

- UWIC competitive with JPEG 2000, SPIHT-AC, and GTW.
- Developed in Java from scratch by two undergraduates in 2 months.
- Still a few glitches that have to be worked on.