Group Testing (Dorfman 1943)

• Given n items, with s items significant
• Use group tests to identify significant items
  – Group test of size k
    • Group is insignificant: all k items insignificant
    • Group is significant: at least one significant
• Goal: Minimize number of group tests

Group Testing (Dorfman 1943)
Zerotree Coding as Group Testing

- Coefficients = items
- Testing trees for significance = group test
- Zerotree coding = one particular group testing algorithm
- Zerotree coding & group testing have similar goals

Hwang’s Group Testing Algorithm (1972)

- Repeat a Group Iteration until all significant items are found
- Group Iteration
  - Test group G containing k unidentified items
  - If G is significant, find a significant item in \( \log_2 k \) tests
    - Each subsequent test is a subset of G
    - Size of test group is halved each time

Group Iteration of size 8

<table>
<thead>
<tr>
<th>Group Test Result</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>I I I I I I I I</td>
<td>0</td>
</tr>
<tr>
<td>I I I I I I I I ?</td>
<td>1</td>
</tr>
<tr>
<td>I I I I I I I I ?</td>
<td>0</td>
</tr>
<tr>
<td>I I I I I I I I ?</td>
<td>1</td>
</tr>
<tr>
<td>I I I I I I I I ?</td>
<td>0</td>
</tr>
</tbody>
</table>

- Equivalent to elementary Golomb code of order 8

Group Testing for Wavelet Image Coding (GTW)

- Hong and Ladner (2000)
- New method for encoding significance pass:
  - Uses Hwang’s Group Testing Algorithm
  - Divide wavelet coefficients into classes
  - Every group test performed is on coefficients in the same class
  - No arithmetic coding

GTW Significance Pass Overview

- Repeat until all coefficients are coded
  - Pick a set of coefficients from the class that is most likely to have significant coefficients.
  - Do one group iteration on the set. The group size is determined by the adaptive group tester.
    - Output the results of the group tests
    - If a significant coefficient is found then
      - Output its sign
      - Update classes of neighboring coefficients
GTW’s adaptive group tester

• Choosing group iteration size k:
  – Ramp up: start with k=1
  – While group insignificant, double k
  – Steady state: use past history to estimate probability p of insignificance
  • Optimal k using Gallager & Van Voorhis’ (1975) result
    \[ k = \frac{1}{\log_2 p} \]
  
  Same as the adaptive Golomb coding algorithm.

GTW Classes

• Coefficients with similar characteristics put into the same class
• Classes are ordered so that classes with coefficients more likely to be significant are tested first.
  • Class characteristics
    – Significant neighbor count
    – pattern type
    – Subband level

Significant neighbor metric

• Count # of significant neighbors
• Example Neighborhood

Pattern Type

• Accounts for correlation exists between neighbors
  – Example pattern types for a subband

Subband level

• Significant neighbor count
  – children count for at most 1
  – 0,1,2 or 3 or more
• Pattern Types 4 and Subband levels 7
• Total number of classes 112
• Ordering
  – First by significant neighbor count (large to small)
  – Second by pattern type (small to large)
  – Third by subband level (small to large)
Decoding

- Decoding algorithm is identical to the encoding algorithm except
  - Decoder knows the results of group test from the compressed bit stream

GTW Compression Performance

- Compression of Barbara
- PSNR (dB) vs. bit rate (bits/pixel)
- GTW
- SPIHT AC
- SPIHT

Flexibility of Group Testing

- Flexibility
  - Significant data sent first
  - Classes defined to focus of significant data
  - Data can move from class to class
  - We always get a progressive coder
- Applications
  - DCT
  - Lapped Transforms
  - Wavelet Packets

GT-DCT

- Hong, Ladner, Riskin (2001)
- Group testing for the discrete cosine transform.
- We do bit-plane coding of the DCT coefficients.
- DCT classes are defined.
- Group testing done first on the classes that have the smallest group size.
Reorganizing Block Transform Coefficients

GT-DCT Classes
- Based on subband reorganization of coefficients
- Class characteristics
  - Significant neighbor metric
  - Subband level

Significant Neighbor Metric
- Count # of significant neighbors

Subband Level

GT-DCT vs JPEG
- Compression of Barbara
Group Testing Notes

• Group testing provides a unified and flexible way to approach bit-plane coding of transformed images.
  – Need good classes (contexts)
  – Need good group testing algorithms (adaptive Golomb coding works)
• Compression performance is outstanding
• Group testing is quite a bit more time consuming than JPEG and SPIHT.
  – need some good data structures and engineering