Group Testing for Image Compression

Edwin Hong and Richard Ladner.
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The Concept of Group Testing

- Identify Army recruits that were infected with syphilis.
- Instead of test recruits individually, the blood sample of several men could be pooled together and test.
  - If the percentage of infected recruits is small, the laboratory tests are greatly reduced.

The Concept of Group Testing

- Given n items, s of which are significant and n-s are insignificant items.
- The group testing problem itself is to find the best way to identify the s significant items
- Applications are
  - Identifying defective Christmas lights
    - Because the significance is small, testing is reduced.
  - Screening disease
    - When the infected individual size is small, testing is reduced.

Group Testing for Data Compression

- Group testing can also be used for Data compression?! Why?

Group Testing for Data Compression

- Given a binary bit stream as input
  - 1 is significant and 0 is insignificant
  - Use deterministic group test algorithm to encode and decode
  - If a group testing algorithm can minimize the number of group tests, it also minimize the number of bits in the encoder's output

Group Testing for Data Compression

- Example 1: Src 00000000 (Group iteration size 8)

State of Input	Output Bit
???????? 00000000	0

Group Testing for Data Compression

- Example 2: Src 00000110 (Group iteration size 8)

State of Input	Output Bit
????????	1
???? ????	1 0
0000 ?? ??	10 1
0000 ? ? ??	101 0
0000 01 ? ?	1010 1
0000 011 ?	10101 0

Group Testing for Data Compression

- So if the probability of INSIGNIFICANT bits in a given group iteration size is big, the number of bits needed to encode this insignificant group iteration is then small.

Group Testing Code with Group Iteration Size 8

Input bits	*Output bits*
00000000	0
00000001	1000
0000001?	1001
000001??	1010
00001???	1011
0001????	1100
001?????	1101
01??????	1110
1???????	1111

Src 0001????

State of Input	Output Bit
????????	1
????????	1 1
?? ??????	11 0
00 ? ?????	110 0

Group Testing for Data Compression

- All the following cases can produce 1 bit output about half of the time:

Group iteration size	**Probability of insignificance**
1: n0	0.5
2: n0 n1	0.71 0.71
3: n0 n1 n2	0.79 0.79 0.79
4: n0 n1 n2 n3	0.84 0.84 0.84 0.84
…	…

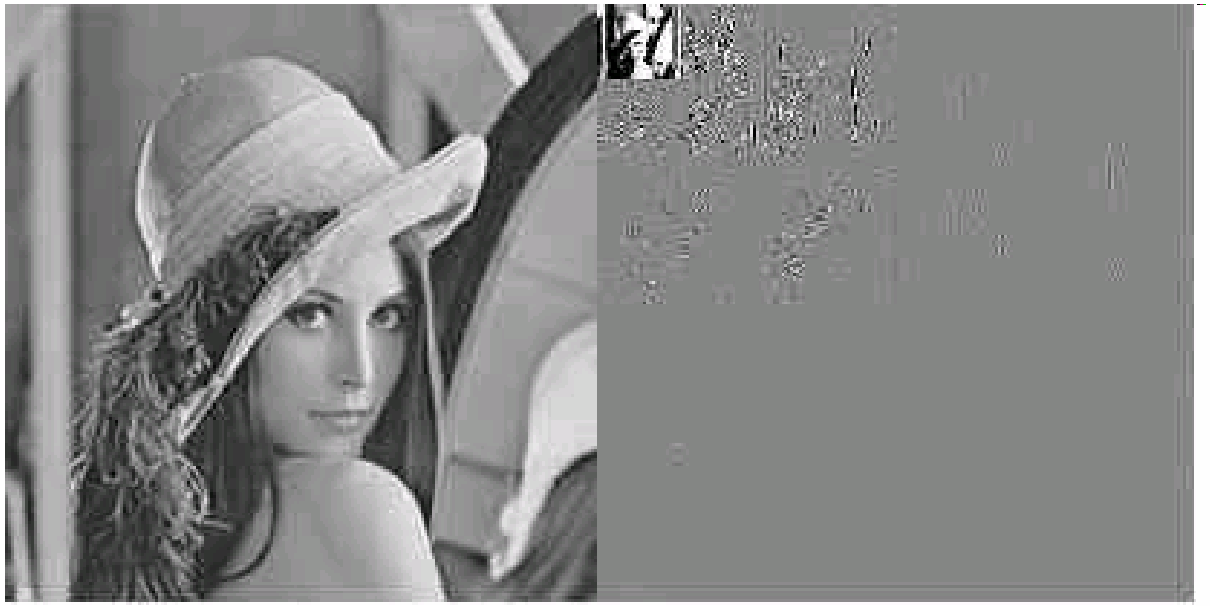
(Group insignificant probability = 0.5)

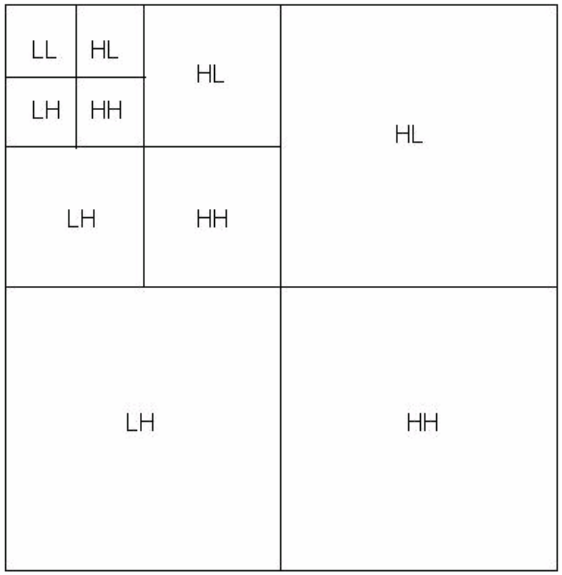
Apply Group Testing

- Key: Choose a best group iteration size to perform group testing
  - The best group iteration size means most likely to produce a fewer output.

Wavelet-based Compression

- Recall, Wavelets compression
  - 3-level wavelet transform of LENA



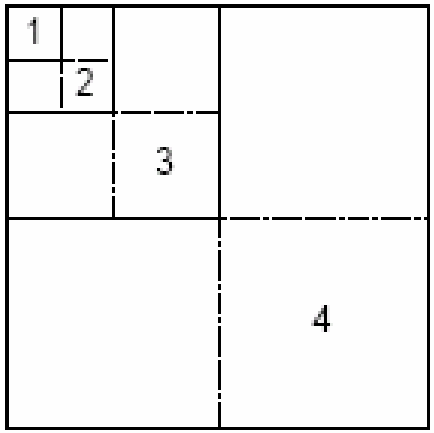


Group Testing for Wavelets (GTW)

- The paper defined classes
  - Subband level
  - Significant neighbor metric
  - Pattern type
- Each class uses a corresponding entropy encoder
  - Such as choose the best group iteration size of a class
- The best compression result is by carefully choosing the group iteration size in each of the defined classes

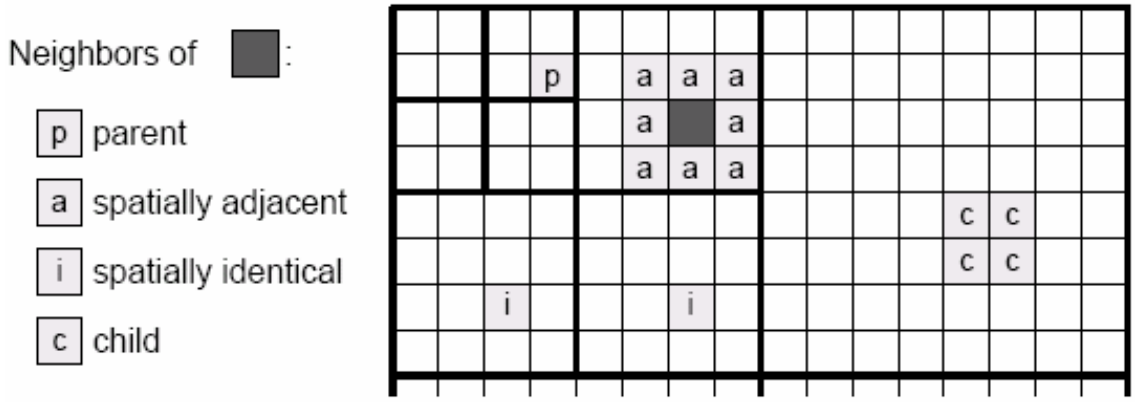
Class: Subband level

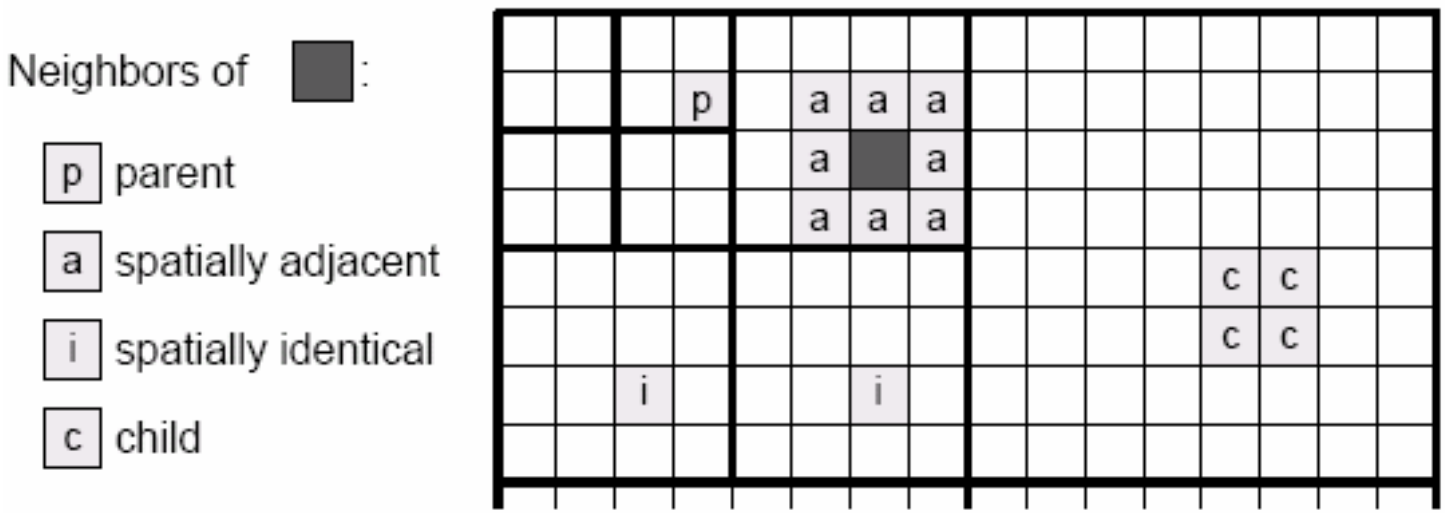
- The lowest frequency subband counts 1.
  - The lower frequency subbands are more likely to be significant.
- Each level of the wavelet transform counts 1.
- Example:
  - 4 subband levels when 3 levels of the wavelet transform are performed



Class: Significant Neighbor Metric

- A coefficient in a bit-plane is likely to be significant if more of its neighbors are significant.
- Defined a significant neighbor metric
  - Can be a value of 0, 1, 2, or 3+ for significant neighbors

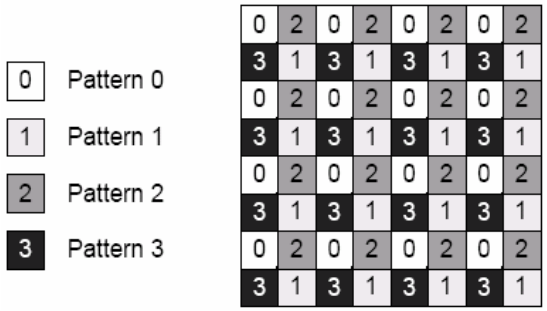


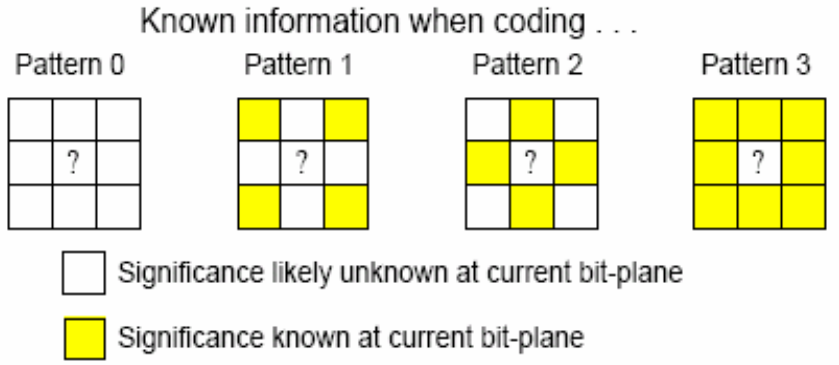


- 8 spatially adjacent coefficients in the same subband (a) counting 1 for each
- 2 spatially identical coefficient in the next lower subband (i) counting 1 for each
- The parent coefficient in the next lower subband (p) counting 1 for each
- The 4 child coefficients (c) counting 1 when any of them are significant
- The max count is then 12 over 15 neighbors.

Class: Pattern type

- Coefficients adjacent to each other are assigned different pattern types.
  - The pattern type is based solely on position in a subband.
  - Make coefficients in any class less likely to be correlated, which means more independent of each other.
- Control the order in which the information known about neighboring coefficients propagates.
  - More info to code Ci+1 than Ci





Experiment

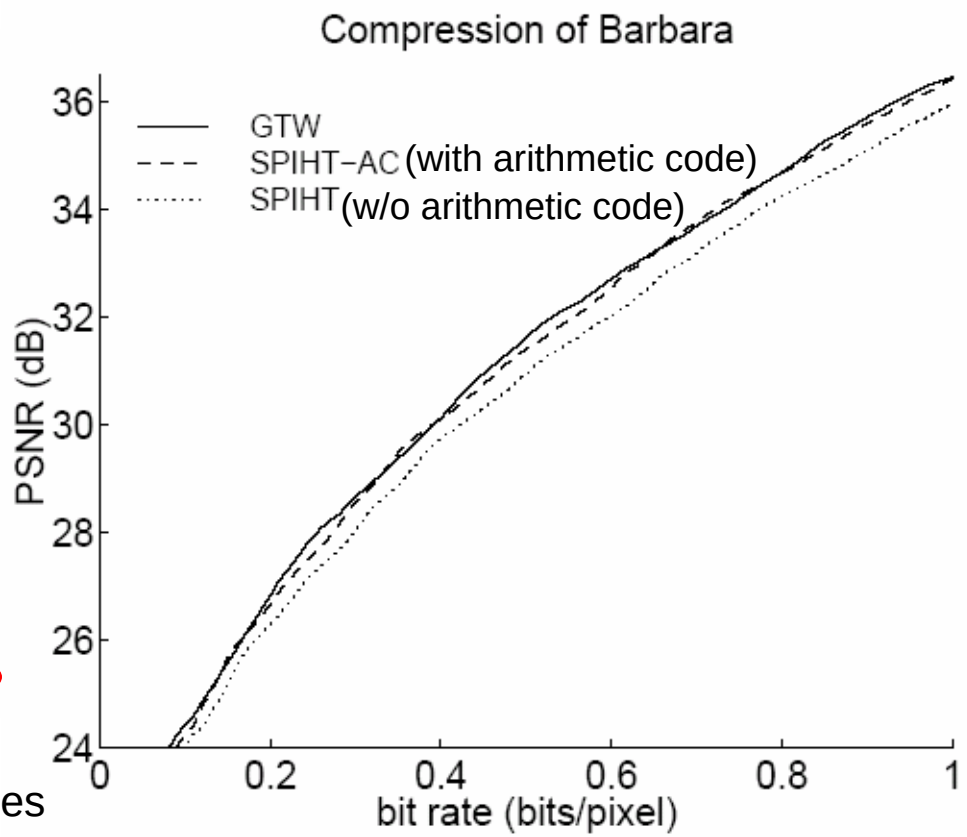
- A GTW class
  - 7 subband levels (6 level of wavelet transform)
  - 4 significant neighbor metric types
  - 4 pattern types
  - Totally 112 classes

Results

- All results are measured in terms of PSNR, in dB.
- The SPIHT-AC rows represent the difference in PSNR between SPIHT-AC and GTW

COMPARISON OF GTW AND SPIHT-AC. Δ SPIHT-AC = SPIHT-AC − GTW.

Image	*Algorithm*	*Rate* (Bits/pixel)			
		0.1	0.25	0.5	1.0
rough wall	GTW	24.37	27.22	29.51	32.51
	Δ SPIHT-AC	+.31	+.10	0.00	−.07
couple	GTW	26.12	29.13	32.41	36.45
	Δ SPIHT-AC	+.05	+.08	+.04	+.13
man	GTW	27.80	31.31	34.13	37.42
	Δ SPIHT-AC	+.32	+.05	+.12	−.15
boat	GTW	27.31	30.93	34.27	39.01
	Δ SPIHT-AC	+.05	+.04	+.18	+.11
tank	GTW	27.50	29.35	31.17	33.86
	Δ SPIHT-AC	−.05	+.01	+.01	−.08
Goldhill	GTW	27.86	30.49	33.09	36.42
	Δ SPIHT-AC	+.08	+.07	+.04	+.13
Lena	GTW	30.17	34.17	37.28	40.45
	Δ SPIHT-AC	+.05	−.06	−.07	−.04
Barbara	GTW	24.41	27.86	31.49	36.42
	Δ SPIHT-AC	−.15	−.28	−.09	−.01



SPIHT: Set Partitioning in Hierarchical Trees
PSNR: peak–signal-to-noise-ratio

Summary

- The author uses Group Testing for Wavelets (GTW) as a compression technique.
- If the probability of insignificant bits in a given group iteration size is big, the number of bits needed to encode this insignificant group iteration is then small.
- The best compression result of GTW is by carefully choosing the group iteration size in each of the defined classes.

References

- “Group Testing for Image Compression.” Edwin Hong and Richard Ladner. IEEE Transations on Image Processing. Vol.11, No. 8, August 2003. 901-911.
- Introduction to Data Compression. Khalid Sayood. Third Edition, 2006. Elsevier Inc.

Questions?