Embedded Zerotree Wavelet

- An Image Coding Algorithm

Shufang Wu

http://www.sfu.ca/~vswu

vswu@cs.sfu.ca

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Agenda

- Overview
- Discrete Wavelet Transform
- Zerotree Coding of Wavelet Coefficients
- Successive-Approximation Quantization (SAQ)
- Adaptive Arithmetic Coding
- Relationship to Other Coding Algorithms
- A Simple Example
- Experimental Results
- Conclusion
- References
- **Q & A**

Overview (2-1)

- Two-fold problem
  - Obtaining best image quality for a given bit rate
  - Accomplishing this task in an embedded fashion
- What is Embedded Zerotree Wavelet (EZW) ?
  - An embedded coding algorithm
  - 2 properties, 4 features and 2 advantages (next page)
- What is Embedded Coding?
  - Representing a sequence of binary decisions that distinguish an image from the “null” image
  - Similar in spirit to binary finite-precision representations of real number

Overview (2-2)
- Embedded Zerotree Wavelet (EZW)

- 2 Properties
  - Producing a fully embedded bit stream
  - Providing competitive compression performance
- 4 Features
  - Discrete wavelet transform
  - Zerotree coding of wavelet coefficients
  - Successive-approximation quantization (SAQ)
  - Adaptive arithmetic coding
- 2 Advantages
  - Precise rate control
  - No training of any kind required

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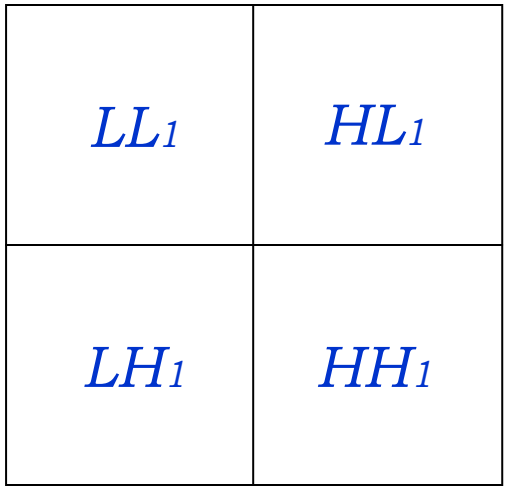
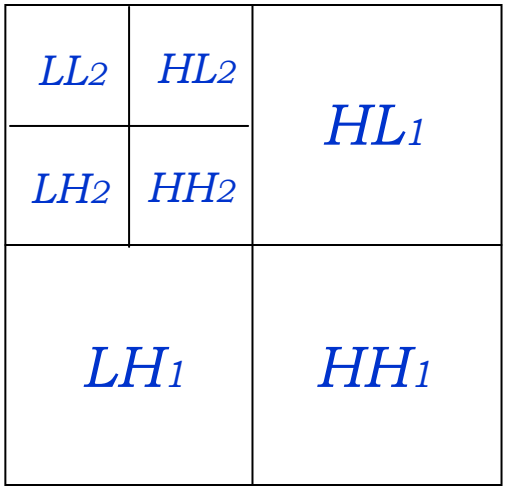
Discrete Wavelet Transform (2-1)

- Identical to a hierarchical subband system
  - Subbands are logarithmically spaced in frequency
  - Subbands arise from separable application of filters



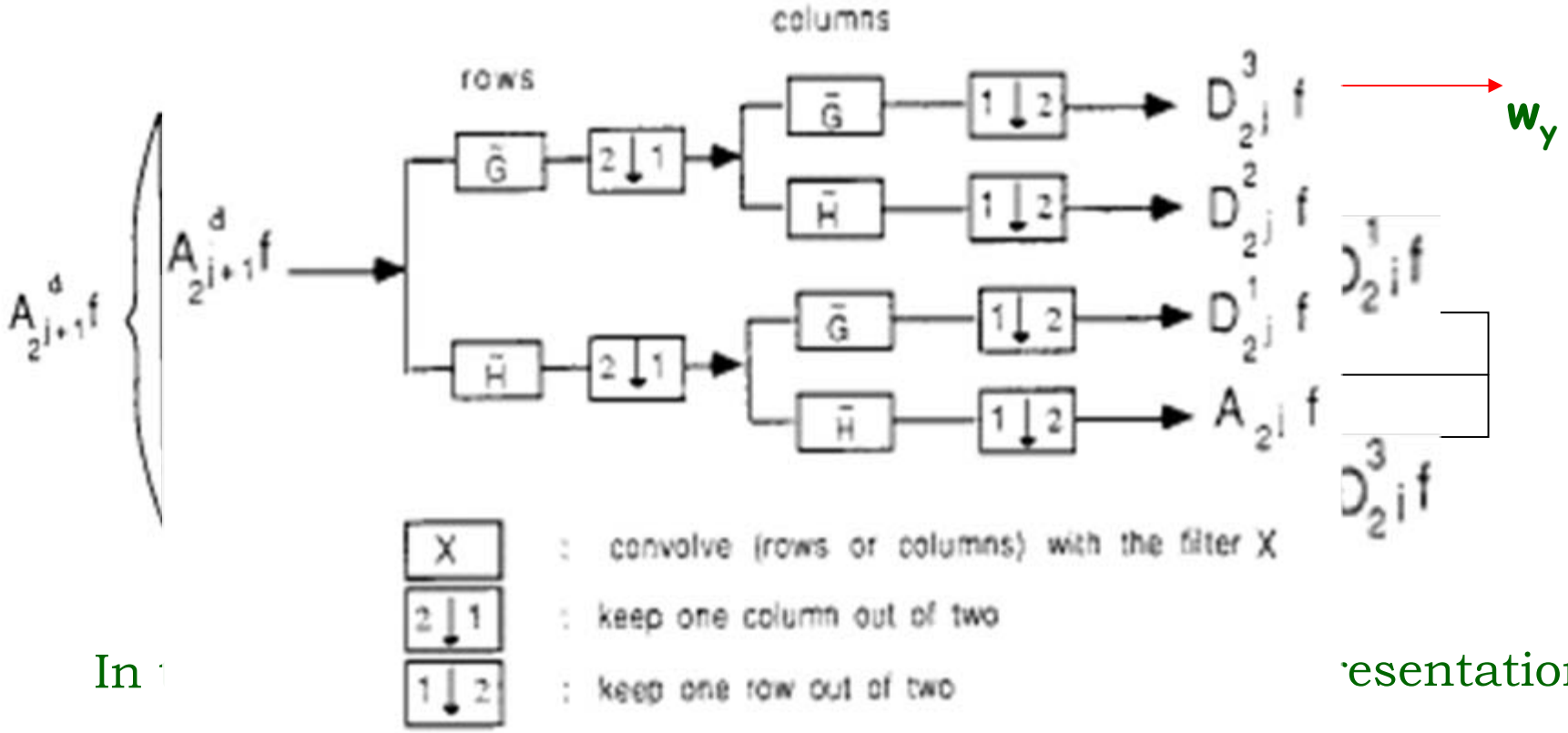
First stage



Second stage

Discrete Wavelet Transform (2-2)

- Wavelet decomposition (filters used based on 9-tap symmetric quadrature mirror filters (QMF))

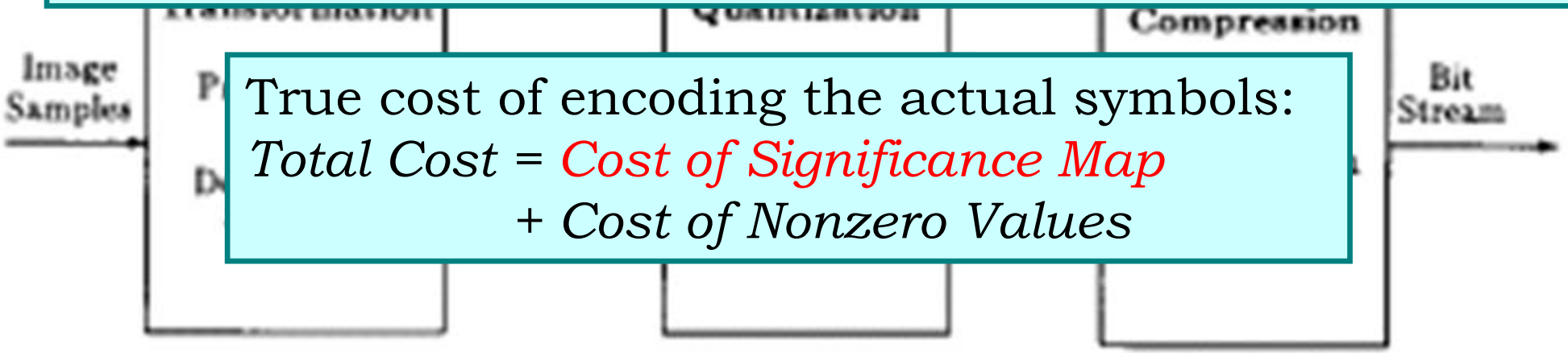


In ... esentations

Zerotree Coding (3-1)

- A typical low-bit rate image coder
  - Large bit budget spent on encoding the significance map

Binary decision as to:
whether a coefficient has a zero or nonzero quantized value

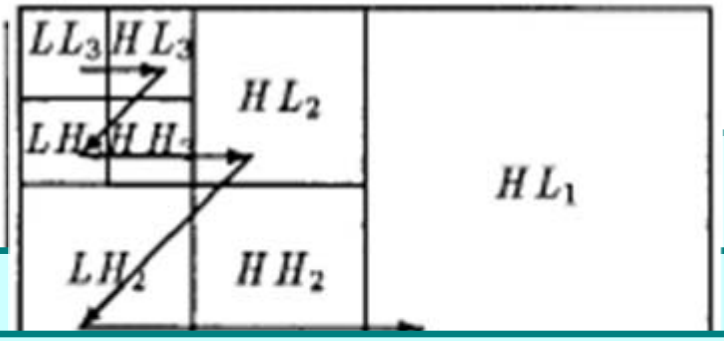


True cost of encoding the actual symbols:
Total Cost = Cost of Significance Map
+ Cost of Nonzero Values

Fig. 3. A generic transform coder.

Zerotree Coding (3-2)

- What is zerotree
  - A new data st



Parent:

Scanning rule:

A coefficient x is

An element of a zerotree for threshold T is

IF

It is not the descendant of a previously found zerotree root for threshold T.

- An elemer

Scanning order of the subbands

- A zerotree root

Zerotree Coding (3-3)

- Encoding

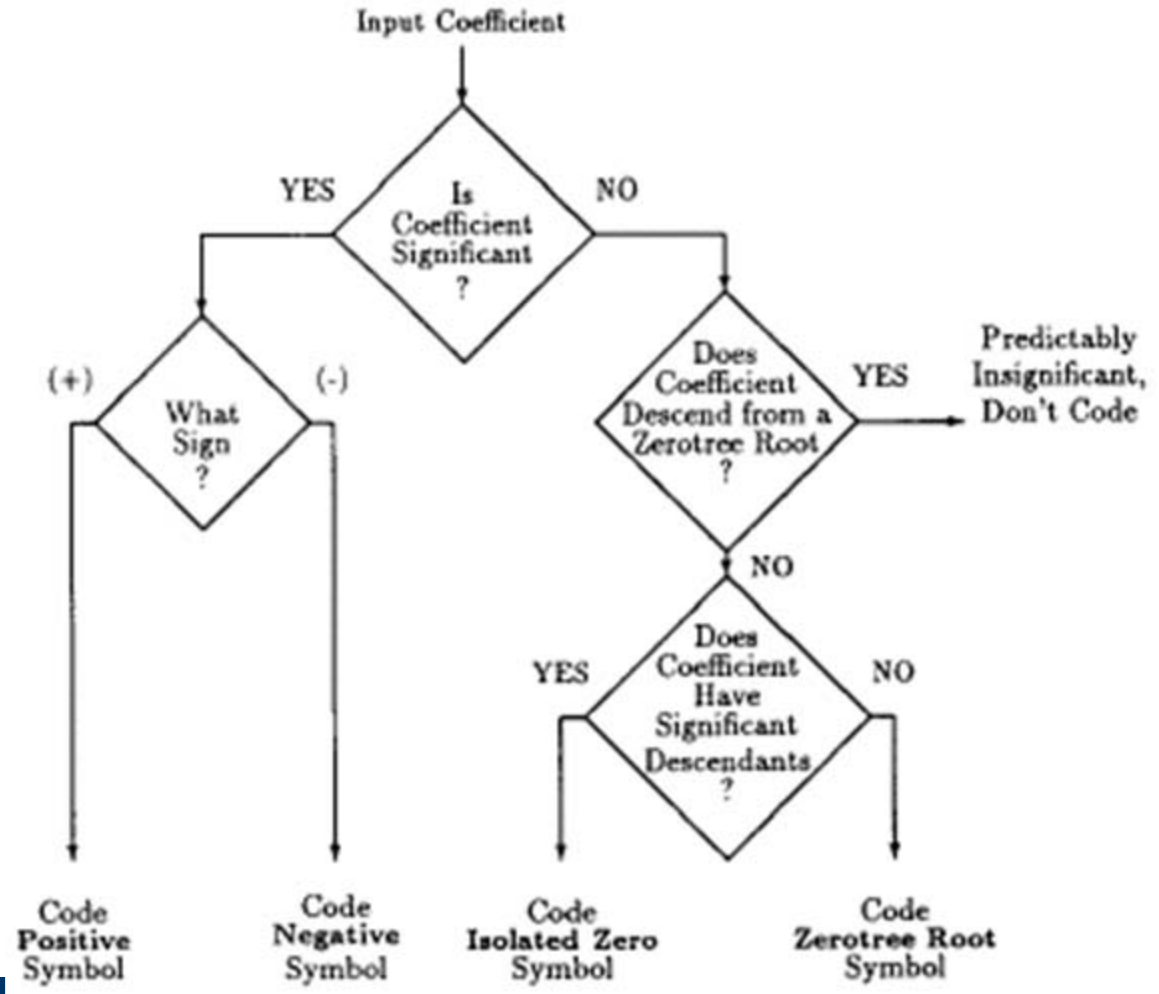


Fig. 6. Flow chart for encoding a coefficient of the significance map.

SAQ (3-1)

- Successive-Approximation Quantization (SAQ)
  - Sequentially applies a sequence of thresholds $T_0,\cdots,T_{N-1}$ to determine significance
- Thresholds
  - Chose so that $T_i = T_{i-1}/2$
  - T_0 is chosen so that $|x_j| < 2T_0$ for all coefficients x_j
- Two separate lists of wavelet coefficients
  - Dominant list

Dominant list contains:

Subordinate list contains:
The magnitudes of those coefficients that have been found to be significant.

SAQ (3-2)

- Dominant pass

During a dominant pass:

During a subordinate pass:

SAQ encoding process:

FOR I = T_0 TO T_{N-1}

Dominant Pass;

Subordinate Pass (generating string of symbols) ;

String of symbols is entropy encoded;

Sorting (subordinate list in decreasing magnitude);

IF (Target stopping condition = TRUE) break;

NEXT;

SAQ (3-3)

- Decoding
  - Each decode symbol, during both passes, refines and reduces the width of the uncertainty interval in which the true value of the coefficient (or coefficients, in the case of a zerotree root)
- Reconstruction value
  - Can be anywhere in that uncertainty interval
  - Practically, use the center of the uncertainty interval
- Good feature
  - Terminating the decoding of an embedded bit stream at a specific point in the bit stream produces exactly the same image that would have resulted had that point been the initial target rate

Adaptive Arithmetic Coding

- Based on [3], encoder is separate from the model
  - which is basically a histogram
- During the dominant passes
  - Choose one of four histograms depending on
    - Whether the previous coefficient in the scan is known to be significant
    - Whether the parent is known to be significant
- During the subordinate passes
  - A single histogram is used

Relationship to Other Coding Algorithms

- Relationship to Bit Plane Encoding (more general & complex)

a) Reduce the width of the largest uncertainty interval in all coefficeints
b) Increase the precision further
c) Attempt to predict insignificance from low frequency to high

Item	*PPC*	*EZW*
1)	First b) second a)	First a) second b)
2)	No c)	c)
3)	Training needed	No training needed

- Relationship to Priority-Position Coding (PPC)

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A Simple Example (2-1)

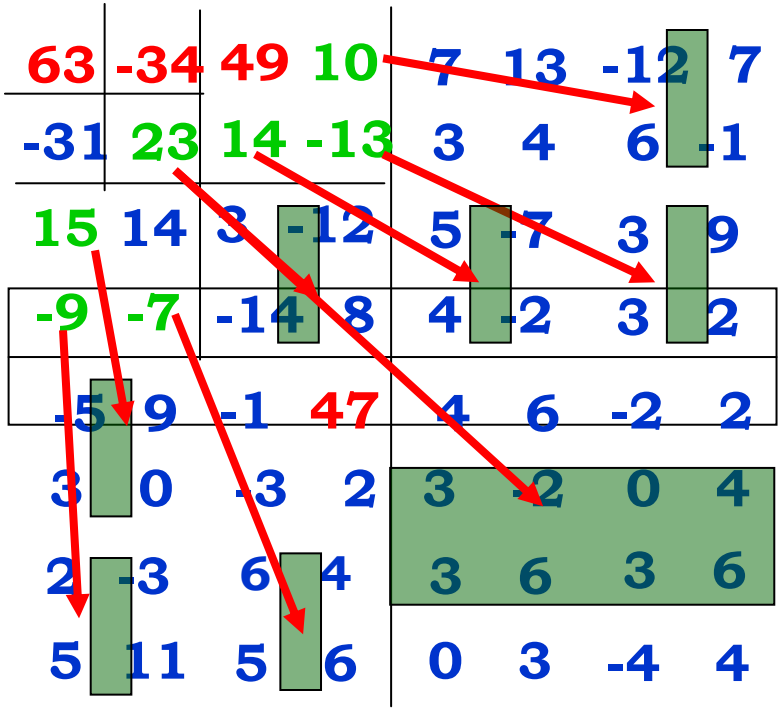
- Only string of symbols shown (No adaptive arithmetic coding)
- Simple 3-scale wavelet transform of an 8 X 8 image
- T_0 = 32 (largest coefficient is 63)

63	-34	49	10	7	13	-12	7
-31	23	14	-13	3	4	6	-1
15	14	3	-12	5	-7	3	9
-9	-7	-14	8	4	-2	3	2
-5	9	-1	47	4	6	-2	2
3	0	-3	2	3	-2	0	4
2	-3	6	4	3	6	3	6
5	11	5	6	0	3	-4	4

Example

A Simple Example (2-2)

- First dominant pass
- First subordinate pass



Example

Comment	Subband	Coefficient Value	Symbol	Reconstruction Value
(1)	LL3	63	POS	48
	HL3	-34	NEG	-48

Coefficient Magnitude	Symbol	Reconstruction Magnitude
63	1	56
34	0	40
49	1	56
47	0	40

Magnitudes are partitioned into the uncertainty intervals [32, 48) and [48, 64), with symbols “0” and “1”.

	LH1	-2	2	0

Experimental Results

- 12-byte header

For image of "Barbara":

For number of significant coefficients retained at the same low bit rate:

Item	*Other*	*EZW*
Number retained	Less	More

(Reason: *The zerotree coding provides a much better way of encoding the positions of the significant coefficients.*)

- Compared with other wavelet transform coding

Conclusion

- 2 Properties
  - Producing a fully embedded bit stream
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References

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Thank You!