ZeroTree Coding

EZW: Embedded ZeroTree Wavelet Encoding

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What is “Embedded”?

- **Progressive**: every bit you “add” - you increase the accuracy of the “number” you transfer - as in: $\pi$

- You can stop at any accuracy you like!

- Now…we need to know what ‘Zerotree’ is … assuming Wavelets is already known.
Coding: Motivation

- In the compression process, the DWT transforms the pixels into coefficients.
- The purpose is to be able to represent the image with minimum number of non-zero coefficients.
- After we have the coefficients, the next mission is to code only the most important coefficients (“non-zero’s”) with minimum bits.
Zerotree Algorithm

• An efficient coding technique, for pyramidal transformations.

• The bit-stream includes information in order of importance: “Msb” first and “Lsb” last, so we have a progressive reconstruction of an image, and we achieve most efficient compression for a pre-defined bitrate.
Pyramidal Transform

• Using DWT, we have a pyramidal construction: within every stage (“scale”) we filter the image and decimate to a lower resolution.

• The result is that for higher scale, the “area” covered by each coefficients is larger than the area covered by the coefficients in the previous scale.
Parent-Child Structure

For each stage (except the first one), every coefficient is calculated as a weighted average of several neighbor coefficients from the previous stage. Every coefficient is a "parent" for the previous related coefficients. Parent-child dependencies of subbands. Note that the arrows point from the subbands of the parents to the subbands of the children.
‘Quad-trees’: Wavelets Coefficients in different sub-bands
A ‘Zero-Tree’

• A quad-tree of which all nodes are equal to or smaller than the root.

• The ‘Tree’ should be coded with a single symbol, and decoded (at the receiver) as a quad-tree, filled with zeros.
The general idea

• **Assumption**: the wavelet coefficients *decrease* with scale:
  – all the coefficients in a quad-tree will be smaller than a threshold if the root is smaller than it
• This assumption can be violated from time to time, but *in practice* its probability is very high
• **The cost**: addition of *zerotree symbol* to the code
Significance of coefficients

• The last coefficient (in the lowest resolution) is the “parent” of the whole image.

• Remember: if a “parent” is Insignificant in a low-resolution image (with reference to a certain threshold), than we assume that all its children are also insignificant (with reference to this threshold !)
Significance Map Coding

Input (coefficient)

Significant?

(+)
Sign?

(-)

Is it a child of a Zerotree?

Y

Got a child?

N

Pos code

Neg code

IZ code

ZT code

Not Coded

Assumed as Insignificant

Zerotree root
Significance Map Coding (cont’d)

• The coefficients which are roots of a zerotree get a special sign (zt), signing that all their children are also neglected.

• Isolated Zero (IZ) is a Zero coefficient, under the threshold but got at least one child that is NOT Insignificant.

• The sign code (pos/neg) is important for the progressive feature.
Coefficients Scan

• Is done in a Zig-Zag way, so that a child could not be scanned before its parent
Scanning Example

Regular scan:  \texttt{hhlh hlhh llll hlhl}

Zerotree scan:  \texttt{hhth hlhh hlhl}

\textit{t: zerotree symbol}, replaces the 4 L’s in the lower left corner + its root
Advantage of Zerotree coding

Better than traditional EOB sign or Run-length

WHY?

See in slide 9:

Assumption: the wavelet coefficients decrease with scale: all the coefficients in a quad-tree will be smaller than a threshold if the root is smaller than it
Important references:

J.M. Shapiro,
“Embedded Image Coding Using Zerotrees of Wavelets Coefficients”

Geoff Davis,
“Wavelet Image Compression Construction Kit”
http://www.cs.dartmouth.edu/~gdavis
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Embedded Zerotree Wavelet Encoding,
http://perso.wanadoo.fr/polyvalens/clemens/ezw/ezw.html