JPEG2000

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ECE 241

JPEG2000 Features

- Superior low bit-rate performance—below 0.25 bpp for highly detailed gray-scale images
- Lossless and lossy compression—lossless compression in the course of progressive decoding
- Progressive transmission by increasing pixel accuracy or spatial resolution

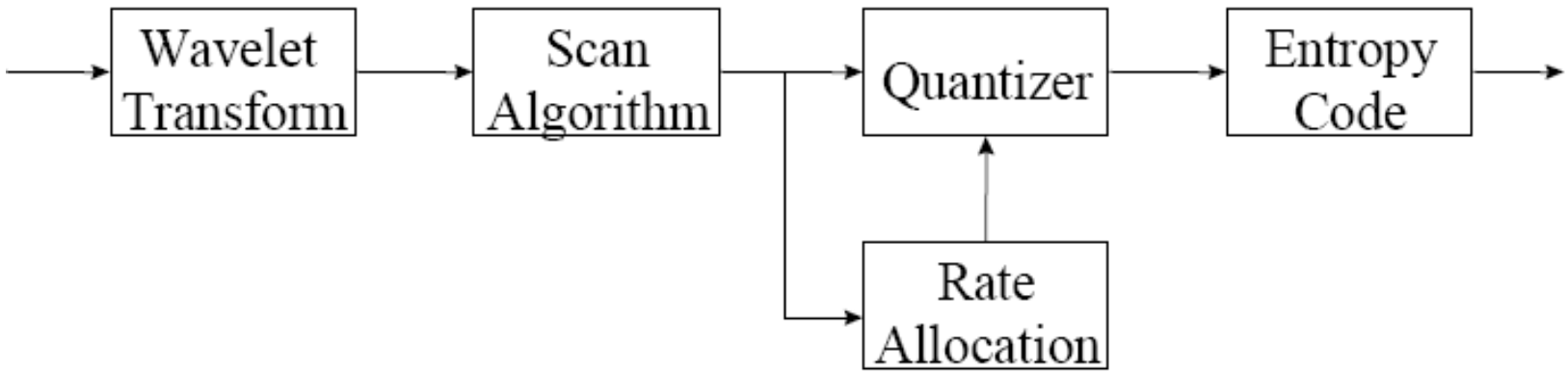
JPEG2000 Features (cont'd)

- Region-of-interest (ROI) coding
- Random codestream access and processing
- Robustness to bit-errors
- Open architecture—a decoder is only required to implement the core tool set and a parser that understands the codestream
- Content-based description

JPEG2000 Features (cont'd)

- Continuous-tone and bi-level compression—compress and decompress images with various dynamic ranges (1 to 16 bit) for each color component

Basic Encoding Diagram



Basic Encoding Steps

- Pre-processing of the image
- The image is decomposed into components
- The image/components are decomposed into tiles
- Tiling refers to partitioning the image into rectangular non-overlapping blocks, called tiles, which are compressed independently as if they are independent images

Basic Encoding Steps (cont'd)

- A wavelet transform is applied on each tile
- Each tile is decomposed into different resolution levels
- The decomposition levels are made up of subbands of coefficients that describe the frequency characteristics of local areas of the tile-component
- The subbands of coefficients are quantized and collected into rectangular arrays of code blocks

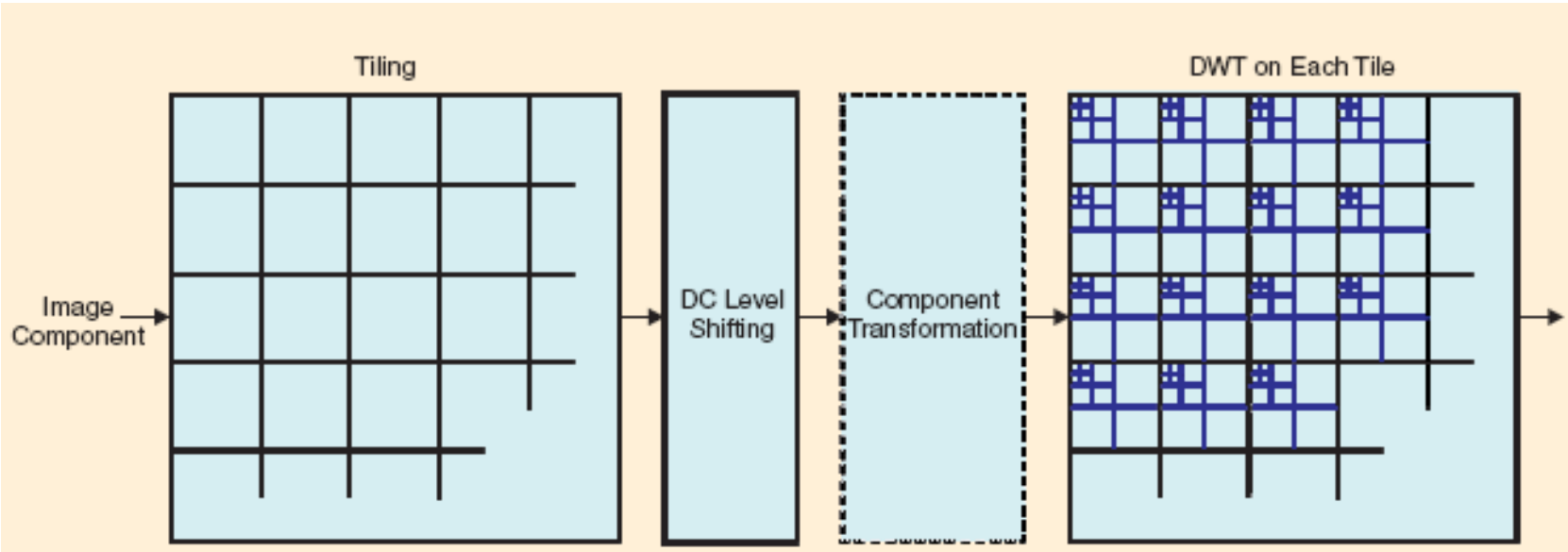
Basic Encoding Steps (cont'd)

- The bit-planes of the coefficients in a cod-block are entropy coded
- ROI's can be encoded in higher quality than the background
- Markers are added in the bitstream for error resilience
- The codestream has a main header that describes the original image and the various decomposition and coding styles

Basic Encoding Engine

- EBCOT—Embedded Block Coding with Optimized Truncation of the embedded bitstreams algorithm

Preprocessing and DWT



Irreversible Component Transformation (ICT)

$$\begin{pmatrix} Y \\ C_b \\ C_r \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.16875 & -0.33126 & 0.5 \\ 0.5 & -0.41869 & -0.08131 \end{pmatrix} \cdot \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 1.0 & 0 & 1.402 \\ 1.0 & -0.34413 & -0.71414 \\ 1.0 & 1.772 & 0 \end{pmatrix} \cdot \begin{pmatrix} Y \\ C_b \\ C_r \end{pmatrix}.$$

Reversible Component Transformation (RCT)

$$\begin{pmatrix} Y_r \\ V_r \\ U_r \end{pmatrix} = \begin{pmatrix} \left\lfloor \frac{R+2G+B}{4} \right\rfloor \\ R-G \\ B-G \end{pmatrix}$$

$$\begin{pmatrix} G \\ R \\ B \end{pmatrix} = \begin{pmatrix} Y_r - \left\lfloor \frac{U_r+V_r}{4} \right\rfloor \\ V_r+G \\ U_r+G \end{pmatrix}$$

Performance Improvement Due to Color Transformation

Table 2. The effect of component transformation on the compression efficiency for the ski image. RCT is employed in the lossless case and ICT in the lossy case. No tiling is used.

	Without Color Transformation	With Color Transformation
Lossless compression	16.88 b/p	14.78 b/p
Lossy compression at 0.25 b/p	25.67 dB	26.49 dB

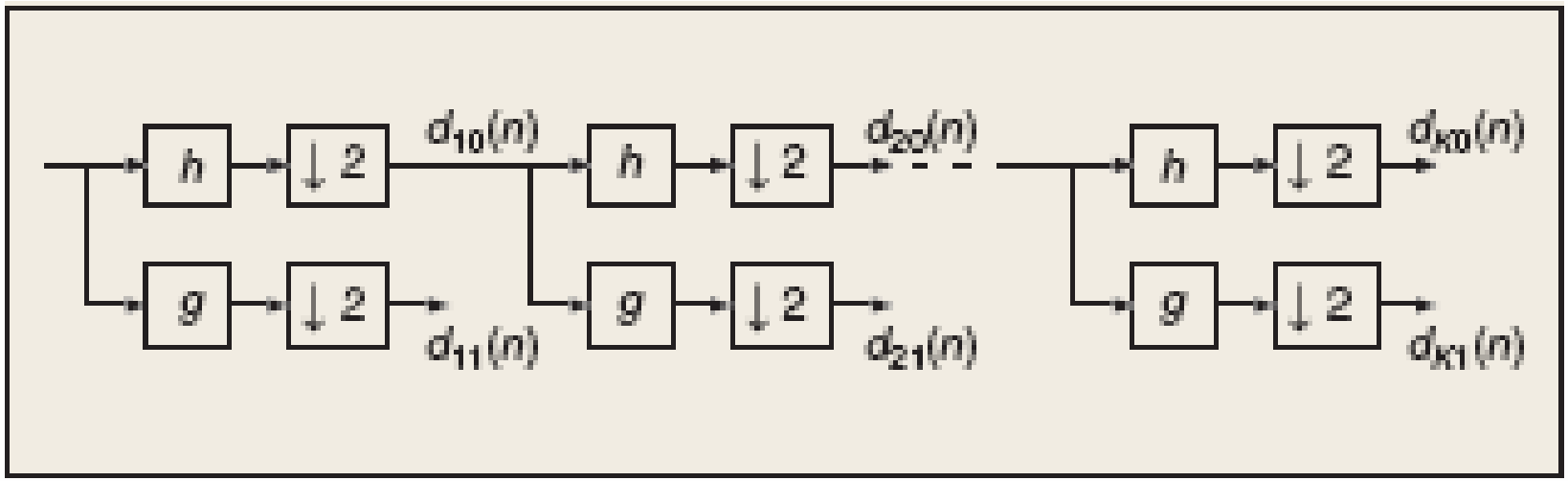
PSNR with Tiling

Tiling / Bit Rate (b/p)	No Tiling	Tiles of Size 128×128	Tiles of Size 64×64
0.125	24.75	23.42	20.07
0.25	26.49	25.69	23.95
0.5	28.27	27.79	26.80

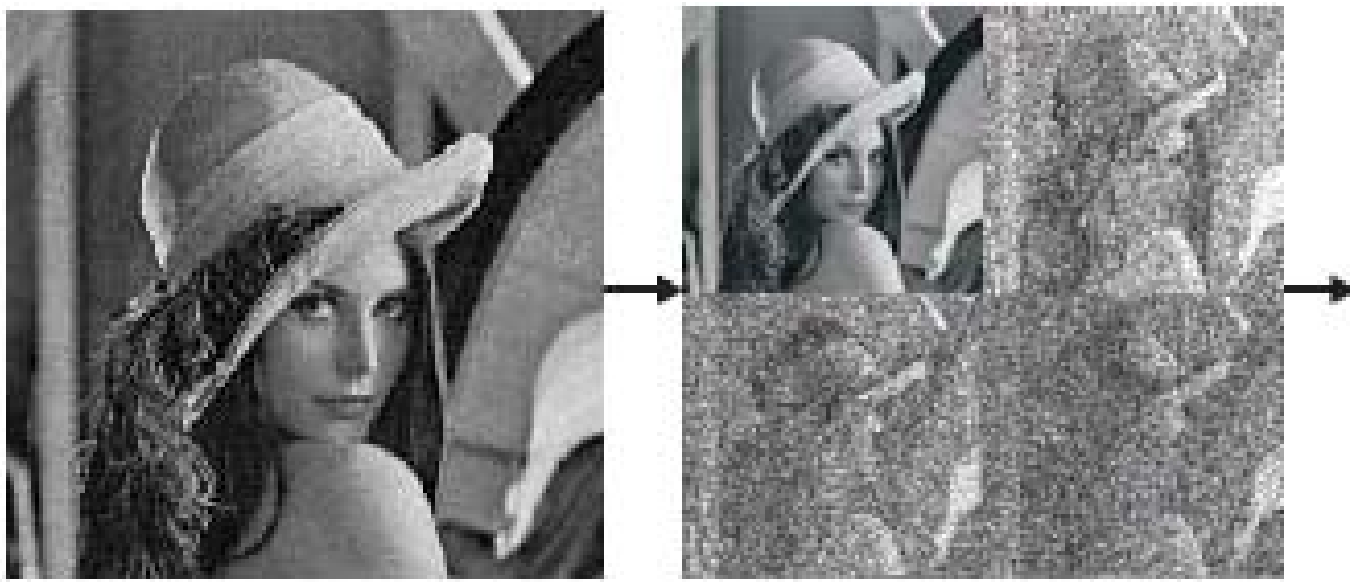
PSNR (in dB) for the color image "ski" (of size 720×576 pixels per component)

Tiling Effects for 64 by 64 Tiles

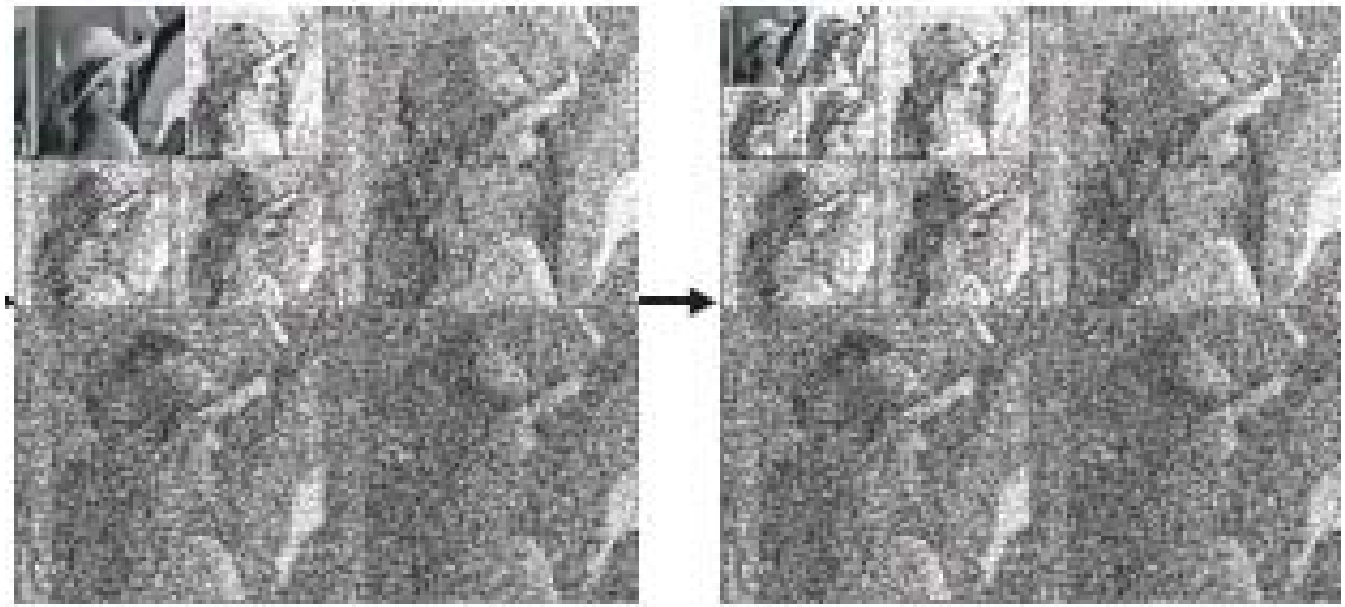
Subband Decompositions



Dyadic Wavelet Decomposition—First Level



Second and Third Levels

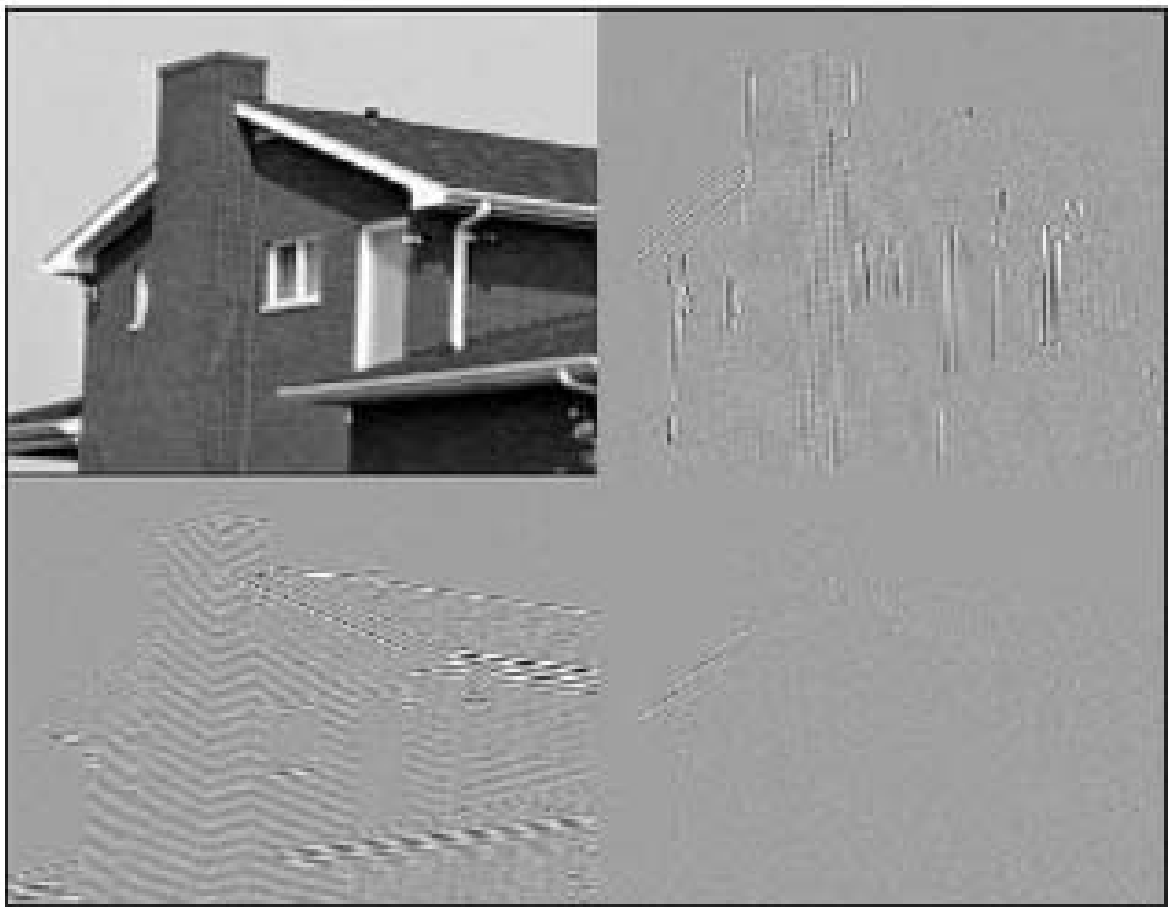


Biorthogonal, Linear Phase Wavelet Filter Coefficients

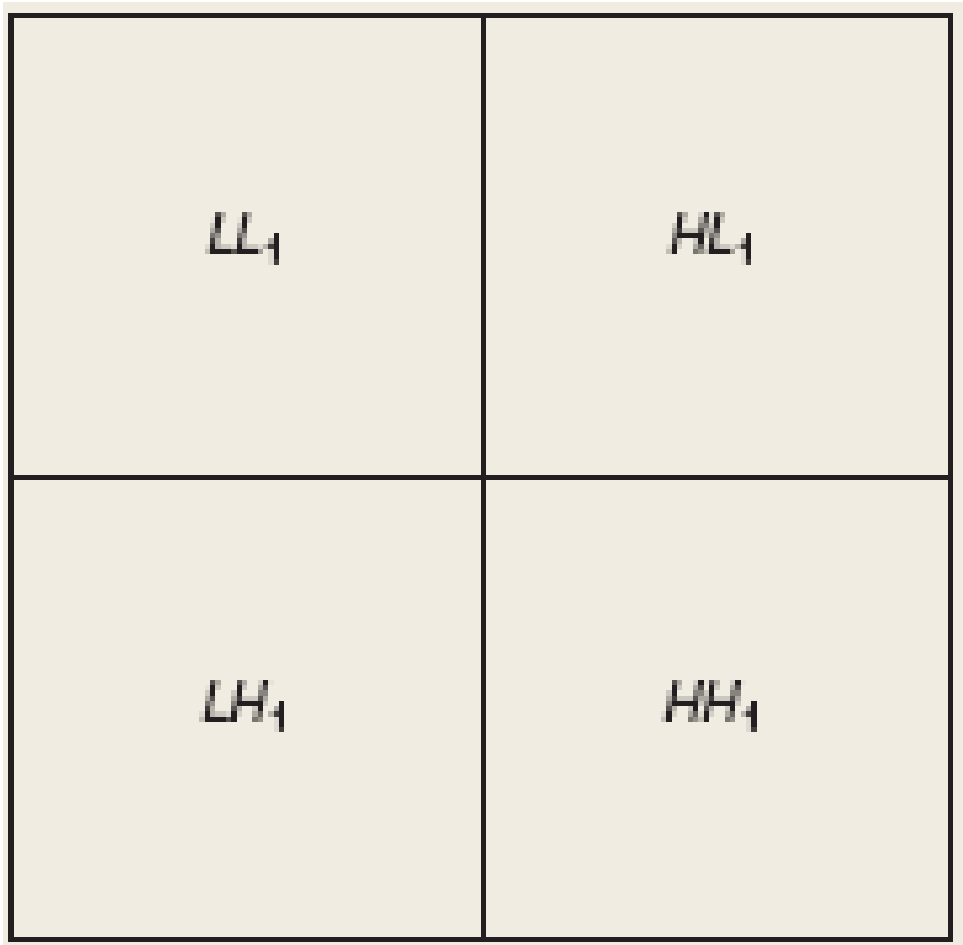
9/7 Filter Coefficients		5/3 Filter Coefficients		Filter Index
h_0	g_0	h_0	g_0	
0.852699	0.788486	1.060660	0.707107	0
0.377402	0.418092	0.353553	0.353553	–1, 1
–0.110624	–0.040689	–0.176777		–2, 2
–0.023849	–0.064539			–3, 3
0.037828				–4, 4

Original Image

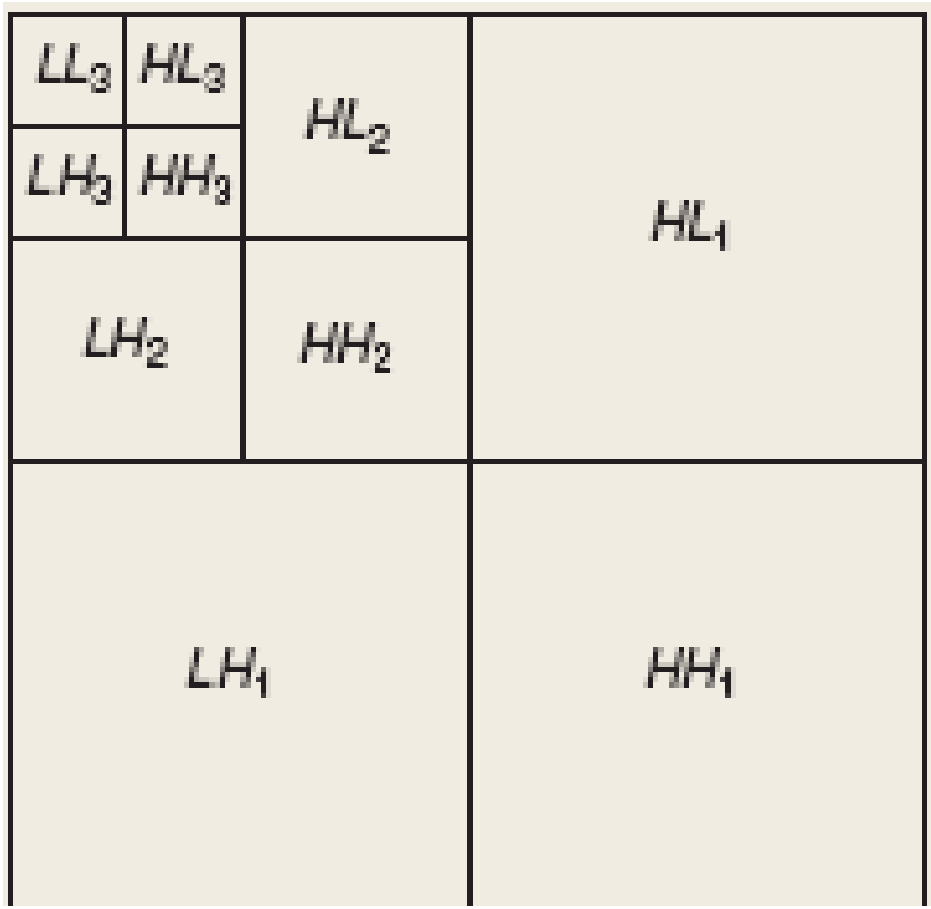
One-Level 2-D Wavelet Transform



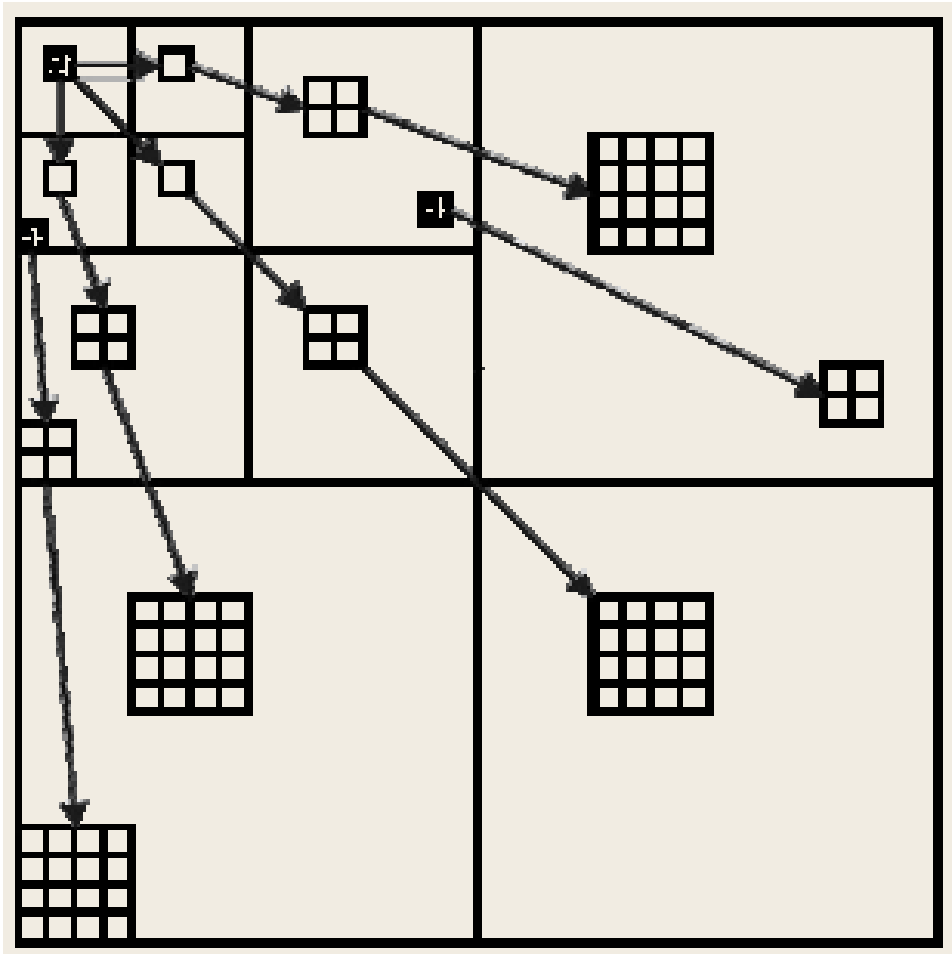
Subband Labeling



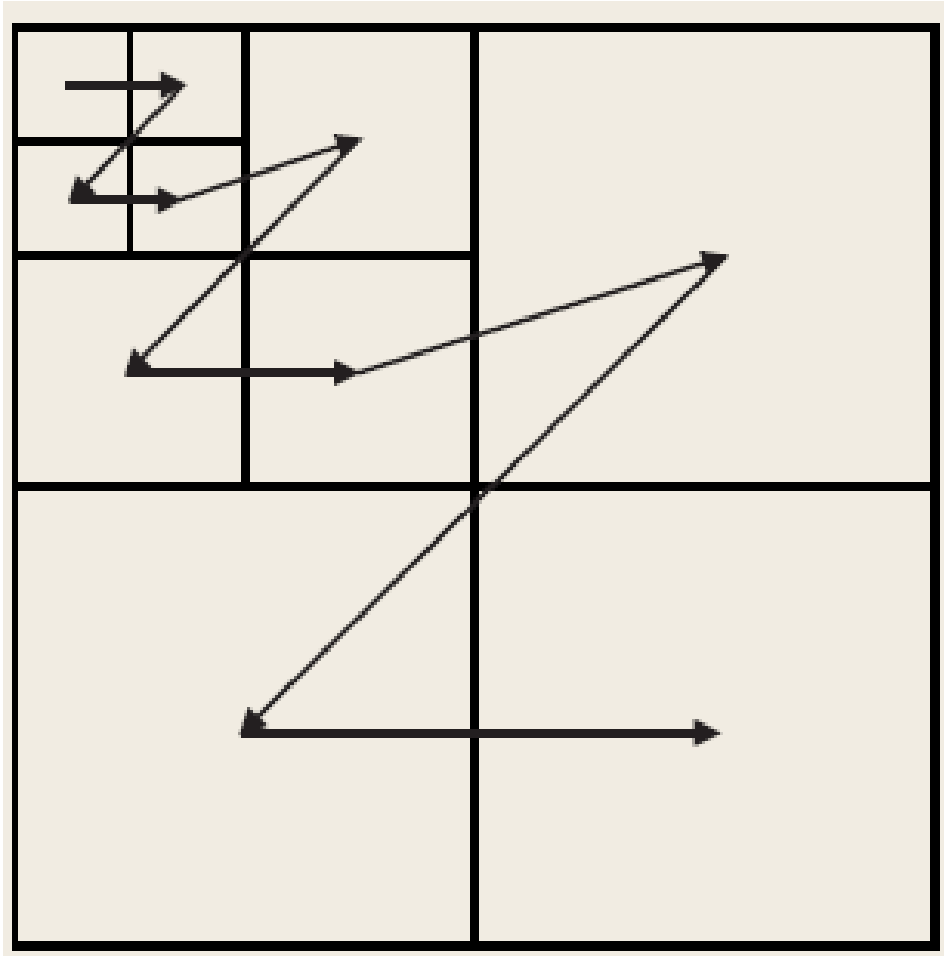
Subband Labeling



Assumed Relationship Between Quadtree Coefficients

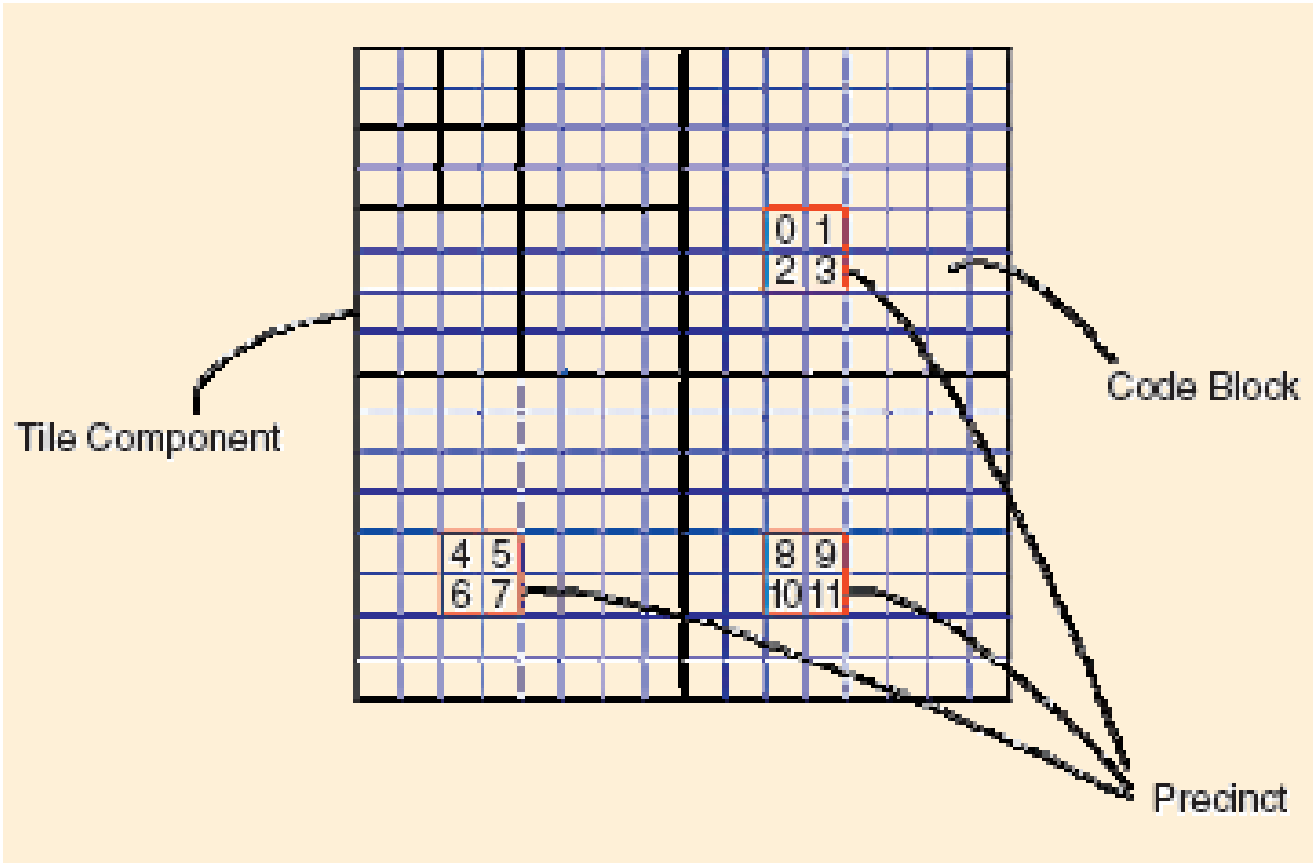


The Scanning Order for Dominant Passes of the EZW Algorithm

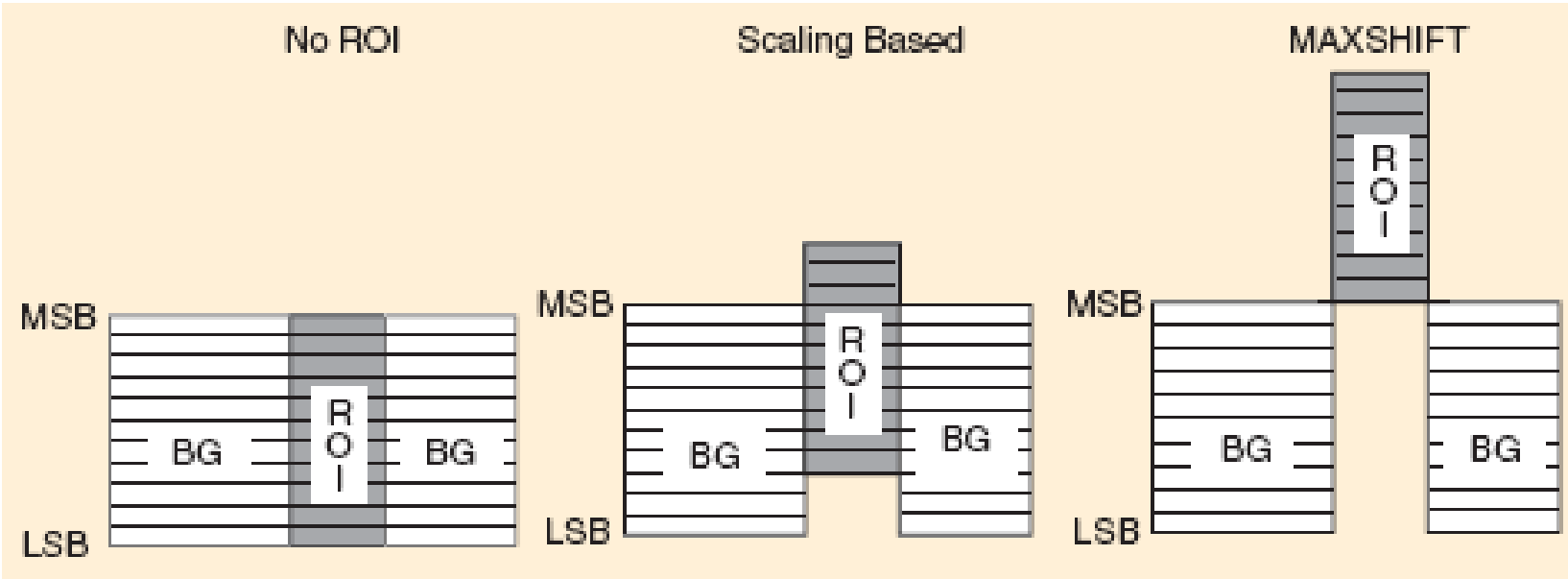


Three-Level 2-D Wavelet Transform

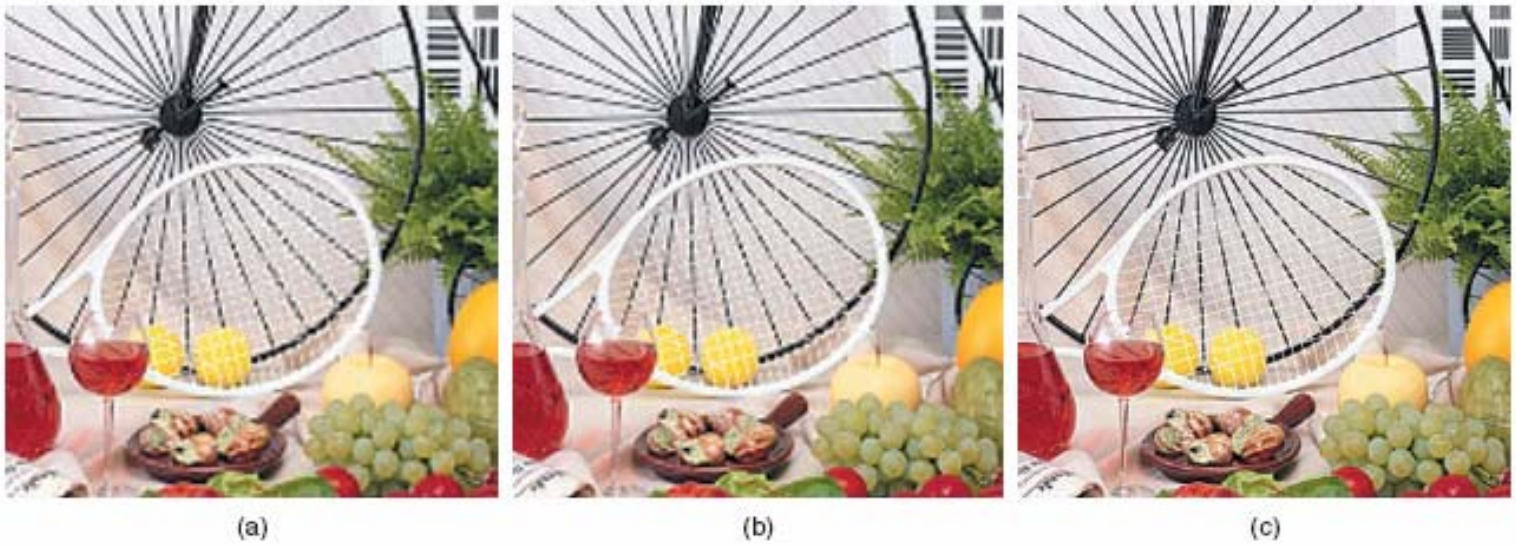
Tiles, Precincts, and Code Blocks



Scaling and Region of Interest (ROI) Coding



SNR Scalability



(a) 0.125 b/p, (b) 0.25 b/p, (c) 0.5 b/p

Progressive by Resolution

Error Resilience Tools

Type of Tool	Name
Entropy coding level	—code blocks —termination of the arithmetic coder for each pass —reset of contexts after each coding pass —selective arithmetic coding bypass —segmentation symbols
Packet level	—short packet format —packet with resynchronization marker

JPEG and JPEG2000 Performance at 0.2 b/p

(a) (b) (c)

JPEG and JPEG2000 Performance at 0.25 b/p

(a)

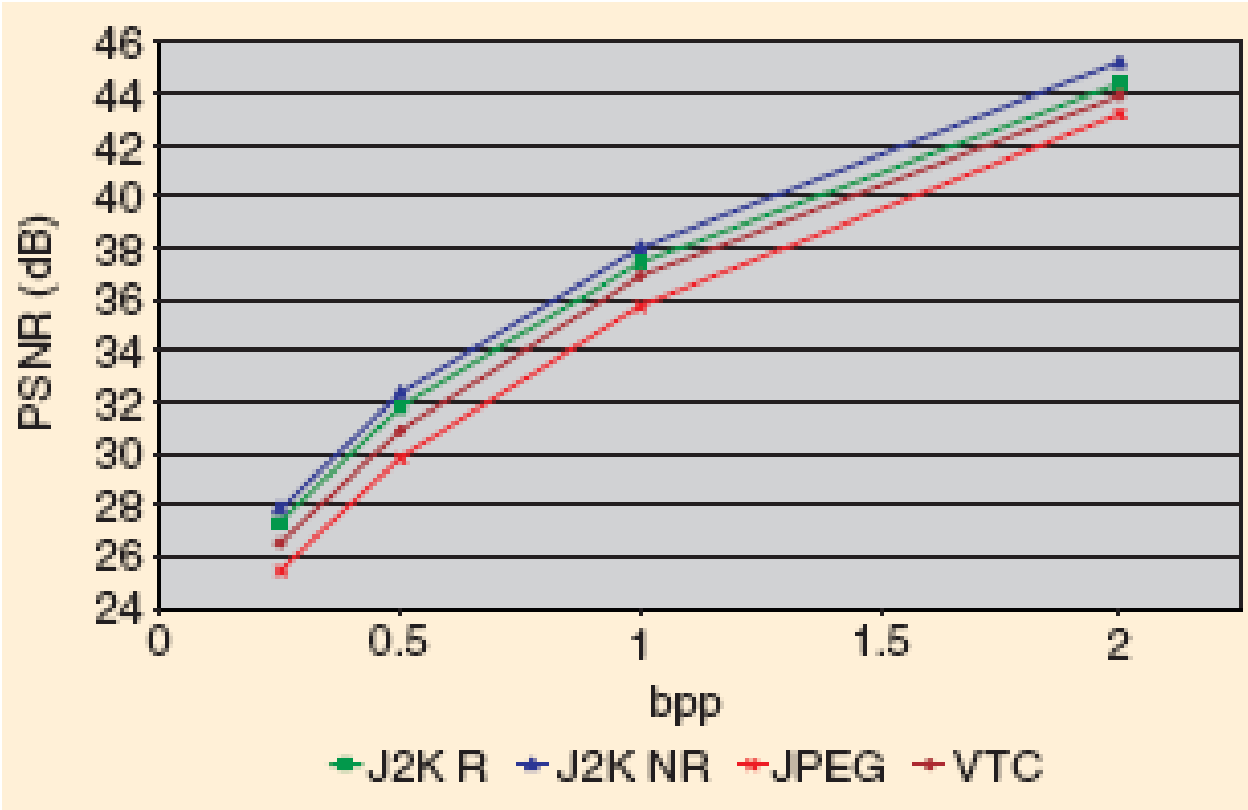
(b)

JPEG and JPEG2000 Performance at 0.5 b/p

(a)

(b)

Lossy Compression Comparisons



Lossless Compression Comparisons

	$J2K_R$	JPEG-LS	L-JPEG	PNG
aerial2	1.47	1.51	1.43	1.48
bike	1.77	1.84	1.61	1.66
cafe	1.49	1.57	1.36	1.44
chart	2.60	2.82	2.00	2.41
cmpnd1	3.77	6.44	3.23	6.02
target	3.76	3.66	2.59	8.70
us	2.63	3.04	2.41	2.94
average	2.50	2.98	2.09	3.52

Error Resilience

Table 8. PSNR results in dB for 200 runs of the decoded cafe image transmitted over a noisy channel for various bit error rates (ber) and compression rates for the JPEG baseline and the JPEG 2000.

b/p	ber	0	1e-6	1e-5	1e-4
0.25	JPEG 2000	23.06	23.00	21.62	16.59
	JPEG	21.94	21.79	20.77	16.43
0.5	JPEG 2000	26.71	26.42	23.96	17.09
	JPEG	25.40	25.12	22.95	15.73
1.0	JPEG 2000	31.90	30.75	27.08	16.92
	JPEG	30.84	29.24	23.65	14.80
2.0	JPEG 2000	38.91	36.38	27.23	17.33
	JPEG	37.22	30.68	20.78	12.09