10 Image Coding Standards

Rationale for Standards

Compatibility

- Standards guarantee data streams that are exchangeable between different devices and applications
- Independence of propriety solutions

Leading edge technology

- Major worldwide research and development is represented at standardization bodies like ITU and ISO/MPEG
- Standards provide reference points for expected quality

Economy of scale

- Standards permit common hardware/software to be used for a wide range of products, thus lowering the cost and shortening the development time

Manufacturer competition

- Exact coding algorithm not defined in a standard, only bit-stream syntax and decoder specification
- Performance of a standardized system is dependent on implementation

10.1 JPEG Standard

JPEG is an acronym for “Joint Photographic Experts Group”

International standard defined by ISO/IEC JTC1/SC29/WG10

ISO – International Organization for Standardization

IEC – International Electrotechnical Commission

JTC – Joint Technical Committee 1 (Information Technology)

SC – Subcommittee 29 (Coding of Audio, Picture, Multimedia and Hypermedia Information)

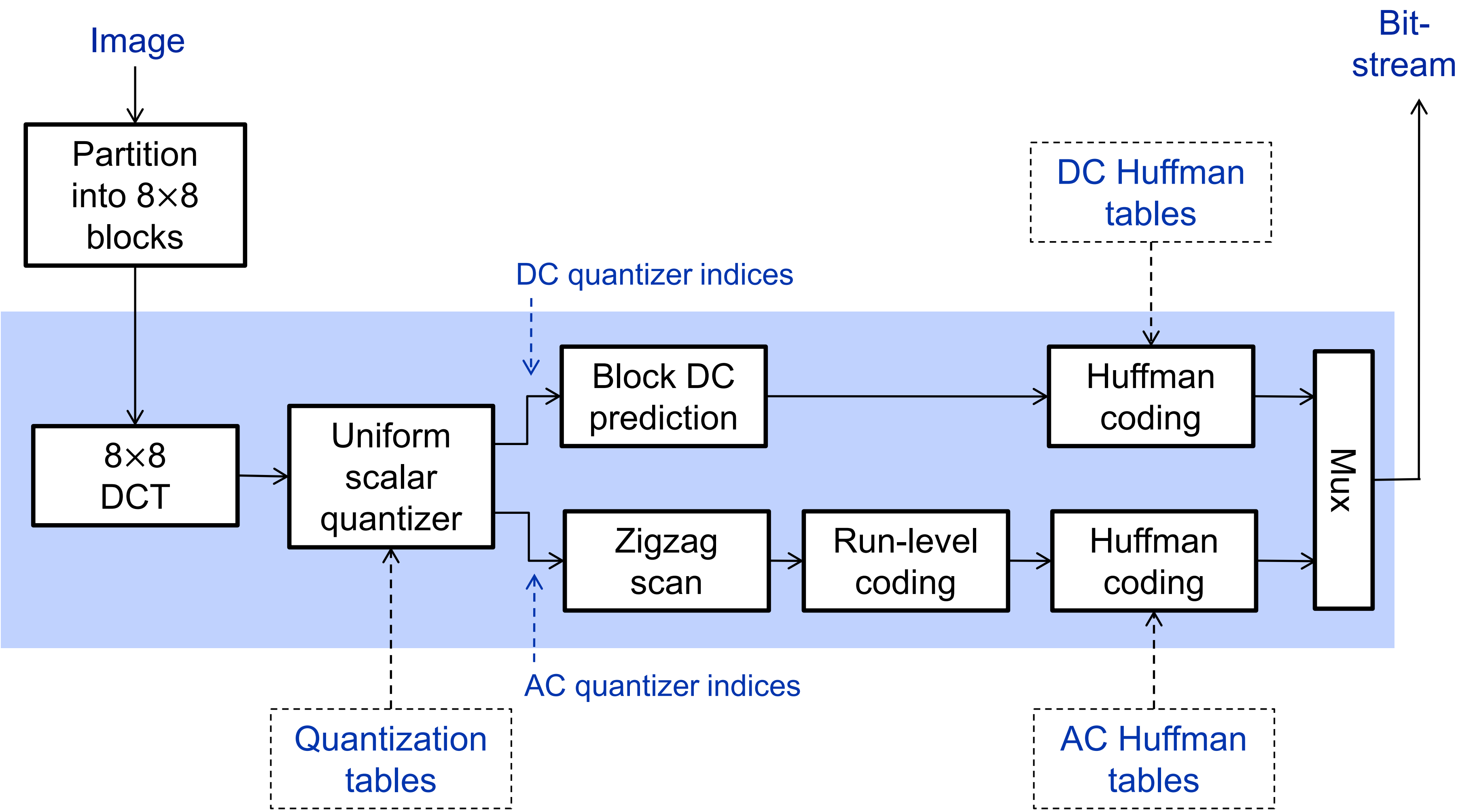
WG – Working Group 10 (Digital Coding and Compression of Still Pictures)

- Formal notation of JPEG is ISO/IEC 10918-1 (also published as ITU-T T.81)
- Work started in 1986, released in 1992

Application areas

- Widely used in digital cameras and for images on the world-wide web
- Motion-JPEG commonly employed for digital video editing

JPEG Baseline System



Quantization Tables

Recommended quantization tables for luminance and chrominance

- Each entry defines quantization step size for frequencies starting top left
- Values based on psychovisual threshold experiments
- Image adapted tables may be transmitted ahead of compressed data stream

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

$Q(k,l)$, Luminance

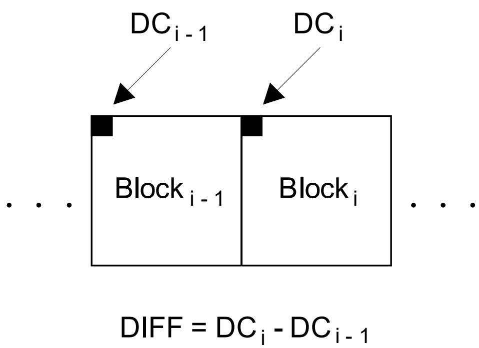
17	18	24	47	99	99	99	99
18	21	26	66	99	99	99	99
24	26	56	99	99	99	99	99
47	66	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99

$Q(k,l)$, Chrominance

Order of Quantized Transform Coefficients

Differential DC encoding

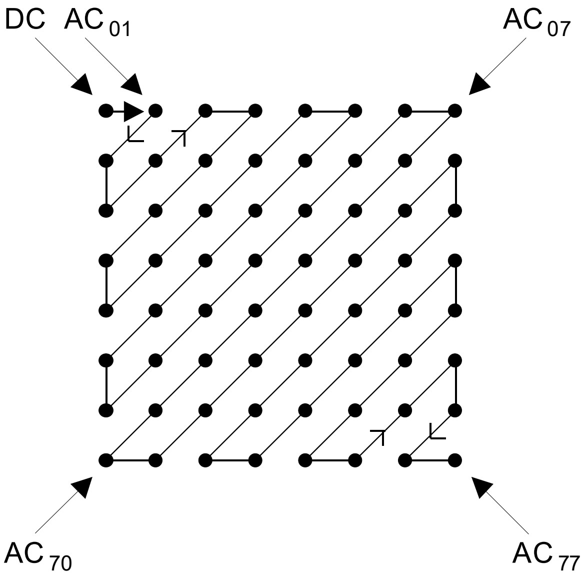
- DC index of previous block is used to predict the DC index of the current block



Differential DC encoding

Zigzag scanning

- AC coefficients are converted into a one-dimensional sequence using zigzag scanning



Zig-zag order

Difference Magnitude Category for DC Coding

SSSS	DIFF values
0	0
1	–1,1
2	–3,–2,2,3
3	–7..–4,4..7
4	–15..–8,8..15
5	–31..–16,16..31
6	–63..–32,32..63
7	–127..–64,64..127
8	–255..–128,128..255
9	–511..–256,256..511
10	–1 023..–512,512..1 023
11	–2 047..–1 024,1 024..2 047

Table for Luminance DC Coefficient Differences

Category	Code length	Code word
0	2	00
1	3	010
2	3	011
3	3	100
4	3	101
5	3	110
6	4	1110
7	5	11110
8	6	111110
9	7	1111110
10	8	11111110
11	9	111111110

Joint Run-Level Coding

- Specify run-length of AC coefficient using four bits “RRRR”
- Specify level of magnitude for subsequent coefficient using “SSSS” bits
- Joint Huffman coding of 8 bit value “RRRRSSSS”, last run signaled by EOB

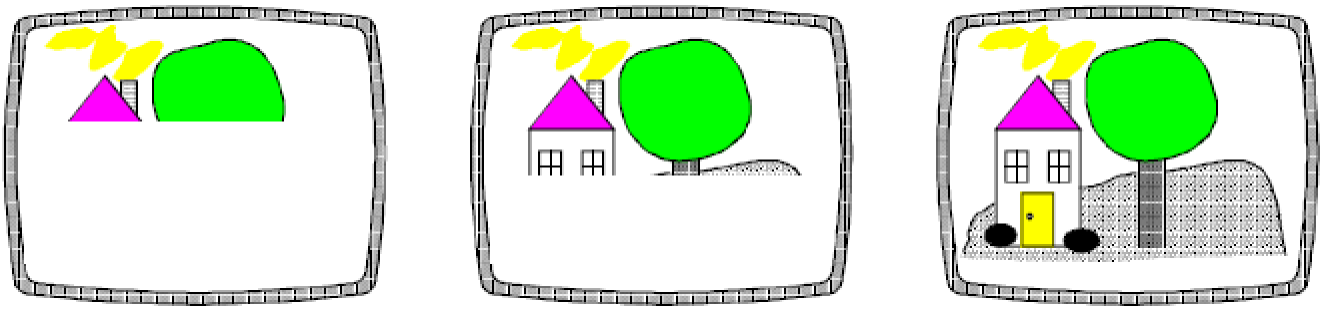
SSSS	AC coefficients
1	–1,1
2	–3,–2,2,3
3	–7..–4,4..7
4	–15..–8,8..15
5	–31..–16,16..31
6	–63..–32,32..63
7	–127..–64,64..127
8	–255..–128,128..255
9	–511..–256,256..511
10	–1 023..–512,512..1 023

Table for Luminance AC Coefficient

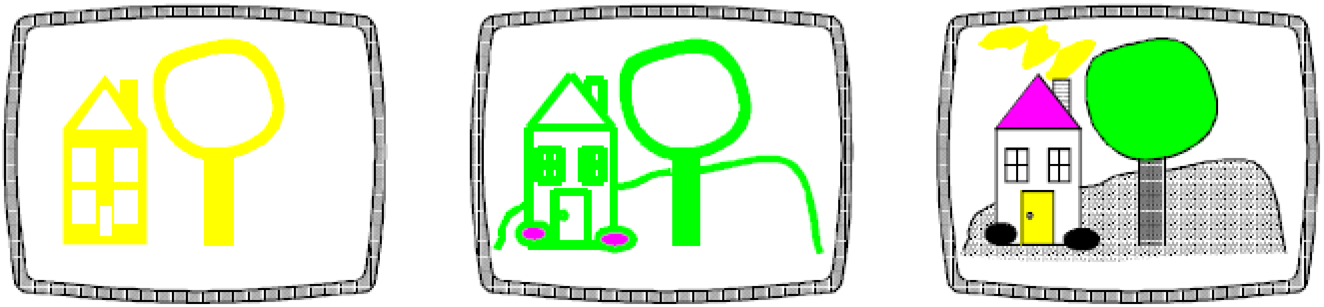
Run/Size	Code length	Code word
0/0 (EOB)	4	1010
0/1	2	00
0/2	2	01
0/3	3	100
0/4	4	1011
0/5	5	11010
0/6	7	1111000
0/7	8	11111000
0/8	10	1111110110
0/9	16	1111111110000010
0/A	16	1111111110000011
1/1	4	1100
1/2	5	11011
1/3	7	1111001
1/4	9	111110110
1/5	11	11111110110
1/6	16	1111111110000100
1/7	16	1111111110000101
1/8	16	1111111110000110

Sequential vs. Progressive Processing

Sequential processing: image is transmitted in scan line fashion from top left to bottom right



Progressive processing: image is transmitted from coarse to fine resolution using progressive encoding



JPEG Progressive Transmission

Spectral selection
- 1st scan DC coefficients only
- 2nd to 64th scan AC-coefficients with increasing frequency

Successive approximation
- 1st scan DC coefficients only
- 2nd to 9th scan MSB to LSB of AC coefficients

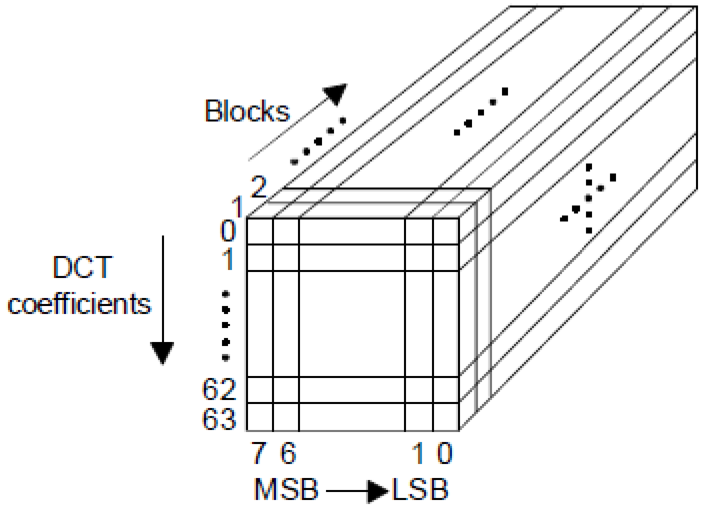
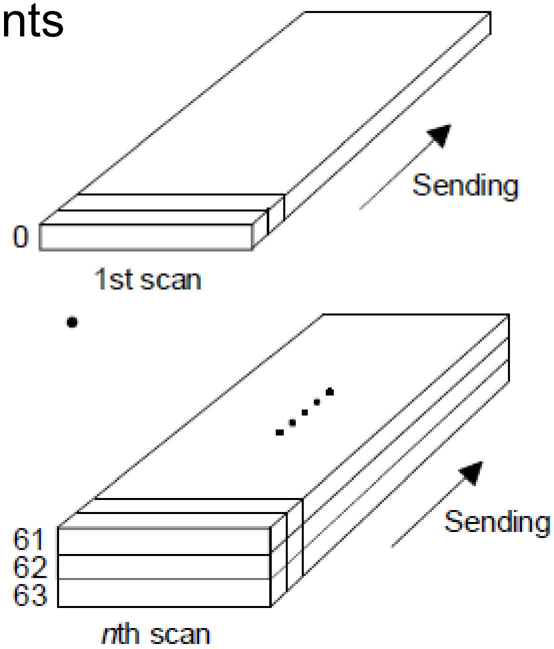


Image as quantized coefficients

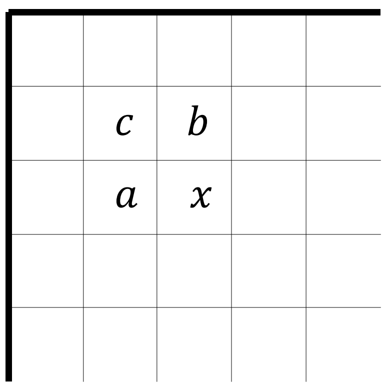


Spectral selection

JPEG Lossless Mode

Linear prediction with Huffman coding of residual

- Predictor can be selected and signaled from set of 8 possibilities
- Less efficient than JPEG-LS



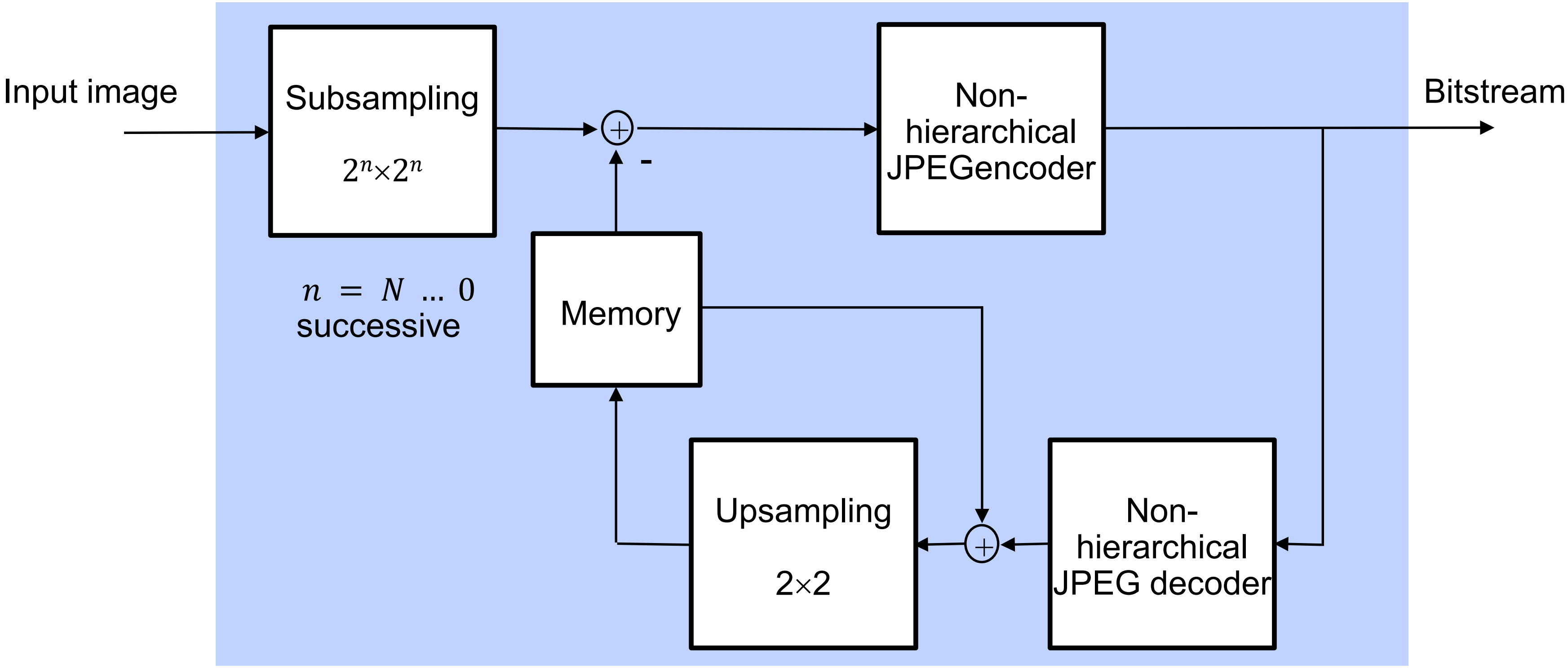
Predictors for lossless coding

Selection Value	Prediction type
0	no prediction
1	a
2	b
3	c
4	$a + b - c$
5	$a + ((b - c)/2)$
6	$b + ((a - c)/2)$
7	$(a + b)/2$

JPEG Hierarchical Mode

Multi-resolution encoding for hierarchical transmission of images

- Build image pyramid by horizontal and vertical downsampling with factor $2^n \times 2^n$
- Encode lowest resolution image using conventional JPEG
- Upsample decoded image with factor 2×2 and use as prediction for the next encoding step



Motion JPEG

Simple method for coding and transmission of video sequences

- Every single frame of a sequence is encoded using JPEG
- Typically applied for archiving video sequences for later frame based cutting and processing
- Usually restricted to the Baseline System

⇨ Motion JPEG is not standardized

10.2 JPEG2000

International standard defined by ISO/IEC JTC1/SC29/WG10

- Formal notation of JPEG2000 is ISO/IEC 15444-1 (also published as ITU-T T.800)
- Released in December 2000

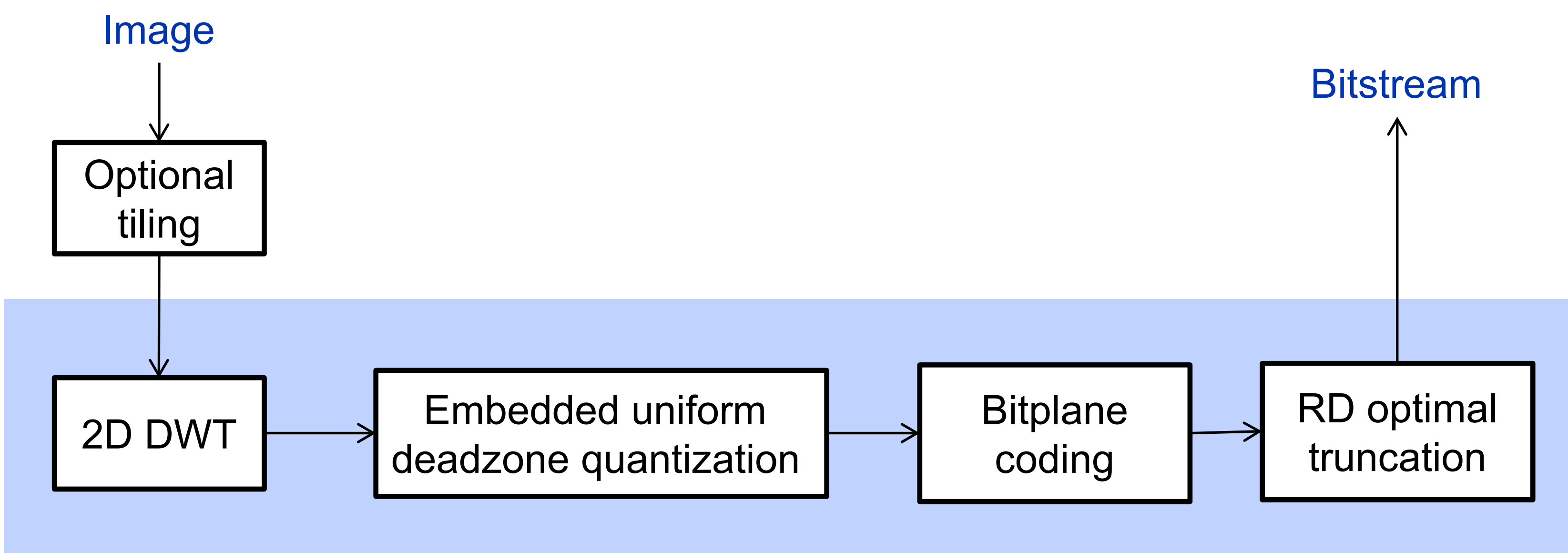
Features

- Improved compression efficiency (~30% less rate than JPEG)
- Embedded bit stream allowing progressive decoding
- Multiple resolution image coding
- Lossy to lossless coding
- Region of interest (ROI) coding

Application areas

- Digital cinema (DCI, “Digital Cinema Initiative”)
- Storage of medical data sets (DICOM, “Digital Imaging and Com. in Medicine”)

JPEG 2000 Encoder Block Diagram



Basic principle: subband coding using discrete wavelet transform

- Optional tiling of image into rectangles for independent coding
- Two filters allowed in DWT
  - Reversible integer (5,3) filter for lossless coding capability
  - Daubechies (9,7) floating point filter for best compression efficiency
- Bitplane coding and RD optimal truncation using EBCOT algorithm ("Embedded block coding with optimal truncation")

JPEG2000 DWT Filters

Normative symmetric filters in wavelet transform for image decomposition:

	Filter length						
$h_0[n]$	5	0.75	0.25	-0.125			(5,3) Bi-orthogonal filter
$h_1[n]$	3	1	-0.5				
$h_0[n]$	9	0.6029	0.2668	-0.0782	-0.0169	0.0267	(9,7) Daubechies filter
$h_1[n]$	7	1.1151	-0.5913	-0.0574	0.0913		
n	=	0	1	2	3	4	

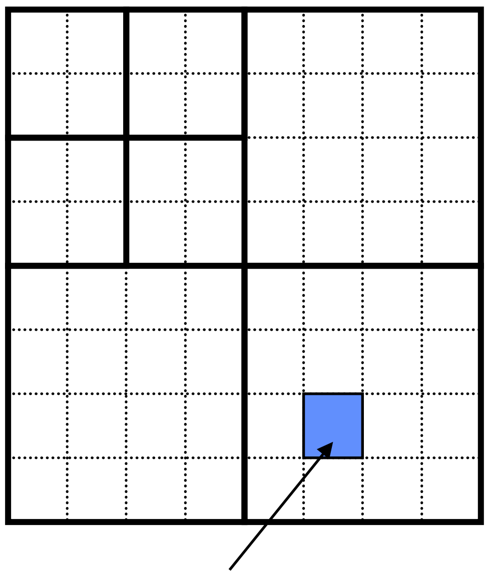
- For bi-orthogonal filter banks, synthesis filters are related to analysis filters by "alias cancellation" relation

$$g_0[n] = (-1)^n h_1[n-1]$$
$$g_1[n] = -(-1)^n h_0[n-1]$$

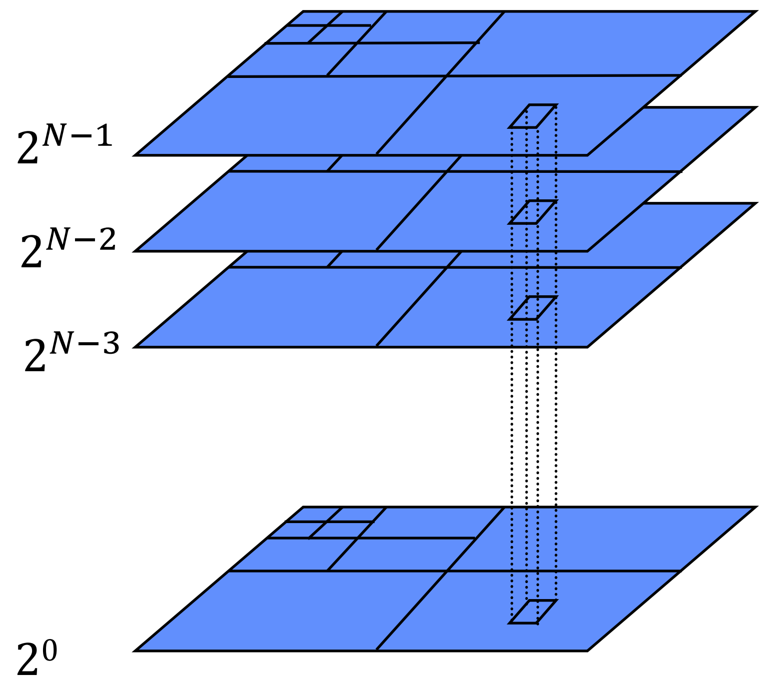
- Synthesis filters can be derived from transmitted analysis filters

JPEG 2000 Block-Based Entropy Coder

- Each subband is further broken down into blocks (32×32 or 64×64)
- Bit-plane of each block are coded depending on neighboring planes in a three pass process using EBCOT algorithm



Block of a subband



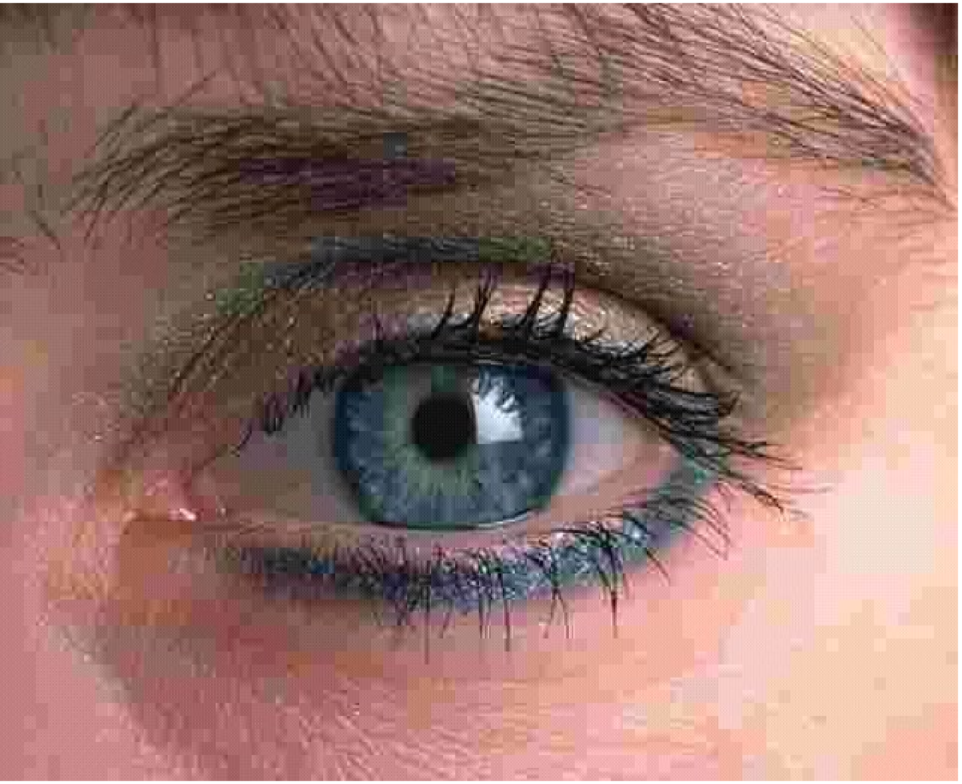
Scalability by resolution or SNR

10.3 Coding Examples

JPEG
Compression ratio 1:81.8
PSNR = 20.9 dB

JPEG 2000
Compression ratio 1:80.9
PSNR = 21.7 dB

Coding Examples



JPEG
Compression ratio 1:80.9
PSNR = 27.2 dB

JPEG 2000
Compression ratio 1:80.4
PSNR = 27.9 dB

Coding Examples

JPEG coded: image size 768×512 pixel; 24 bit color, compression ratio 1:48

Coding Examples

JPEG 2000 coded: image size 768×512 pixel; 24 bit color, compression ratio 1:48

RD Comparison JPEG vs. JPEG 2000