JPEG2000

The next generation still image coding system

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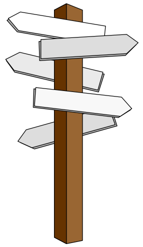
Standards Organizations

- International Organization for Standardization (ISO)
  - 75 Member Nations
  - 150+ Technical Committees
  - 600+ Subcommittees
  - 1500+ Working Groups
- International Electrotechnical Commission (IEC)
  - 41 Member Nations
  - 80+ Technical Committees
  - 100+ Subcommittees
  - 700+ Working Groups

ISO / IEC Terminology

- ISO: International Standardization Organization
- IEC: International Electrotechnical Committee
- ISO/IEC JTC1: Joint Technical Committee
- SC29: Information Technologies
  - WG1: still images, JPEG and JBIG
    - Joint Photographic Experts Group and Joint Bi-level Image Group
  - WG11: video, MPEG
    - Motion Picture Experts Group
  - WG12: multimedia, MHEG
    - Multimedia Hypermedia Experts Group



JPEG: Summary

JPEG (*Joint Photographic Experts Group*)

"Digital Compression and Coding of Continuous-tone Still Images"

- Joint ISO and ITU-T
- Published in 4 Parts:
  - ISO/IEC 10918-1 | ITU-T T.81 : *Requirements and guidelines*
  - ISO/IEC 10918-2 | ITU-T T.83 : *Compliance testing*
  - ISO/IEC 10918-3 | ITU-T T.84: *Extensions*
  - ISO/IEC 10918-4 | ITU-T T.86: *Registration of JPEG Parameters, Profiles, Tags, Color Spaces, APPn Markers Compression Types, and Registration Authorities (REGAUT)*

JPEG: Summary (cont.)

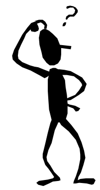
JPEG derived industry standards

- JFIF (*JPEG File Interchange Format,* <xxxxxx.jpg>)
- JTIP (*JPEG Tiled, Pyramid Format*)
- TIFF (*Tagged Image File Format*)
- SPIFF (*Still Picture Interchange File Format, JPEG Part 3*)
- FlashPix
  - Developed by Hewlett-Packard, Kodak, Microsoft, Live Picture (1996)
  - Transferred to Digital Imaging Group (DIG), an industry consortium

JPEG 2000: Image Coding System

Why another still image compression standard?

In order to address areas that the current standards fail to produce the best quality or performance, as for example:



- **Low bit-rate compression**: for example below 0.25 bpp
- **Lossless and lossy compression**: No current standard exists that can provide superior lossy and lossless compression in a single codestream.
- **Computer generated imagery:** JPEG was optimized for natural imagery and does not perform well on computer generated imagery.

Why another still image compression standard? (cont'd)

- **Transmission in noisy environments**: The current JPEG standard has provision for restart intervals, but image quality suffers dramatically when bit errors are encountered.

- **Compound documents:** Currently, JPEG is seldom used in the compression of compound documents because of its poor performance when applied to bi-level (text) imagery.

- **Random codestream access and processing**

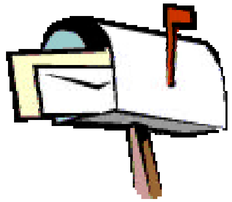
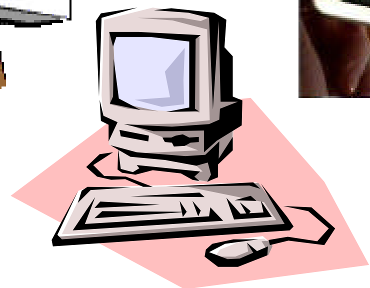
Why another still image compression standard? (cont'd)

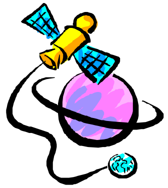
- **Open Architecture:** Desirable to allow open architecture to optimise the system for different image types and applications.
- **Progressive transmission by pixel accuracy and resolution**

JPEG2000
Markets and Applications

- Internet
- Mobile
- Printing
- Scanning
- Digital Photography
- Remote Sensing
- Facsimile
- Medical
- Digital Libraries
- E-Commerce



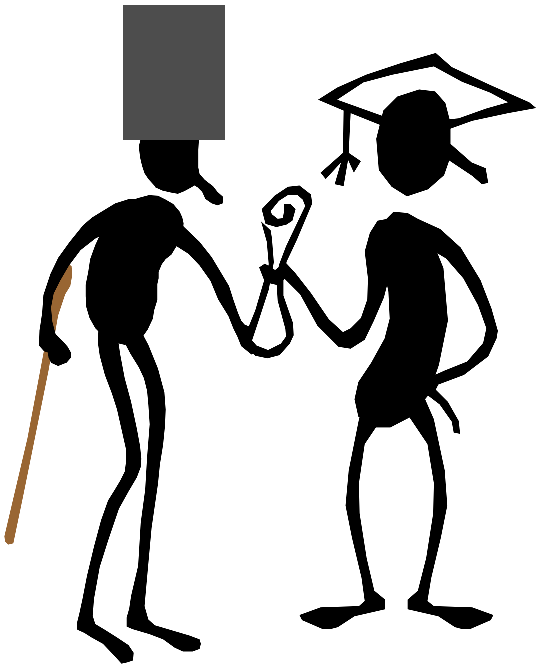








The relation JPEG ⇔ JPEG2000

- JPEG2000 is intended to **complement** and not to replace the current JPEG standards



JPEG2000 contributors

- 21 countries / 80-100 meeting attendees
  - **EUROPE**
    - Ericsson, Nokia, Philips, Canon, Motorola, IMEC, EPFL, NTNU, Technical University of Denmark, VUB, Technical University of Berlin
  - **USA/Canada**
    - Kodak, HP, Rockwell, Motorola, TI, Ricoh, Sharp, Adobe, Sarnoff, SAIC, Teralogic, Univ. of Arizona, Univ. of Southern California, Univ. of Maryland, UBC, RPI
  - **ASIA/Australia**
    - Samsung, Sony, Mitsubishi, CISRA, Univ. New South Wales, Oki, Panasonic, …
- 3-4 meetings per year

JPEG2000 Development

- Timeline
  - Feb 96 (Geneva) started with original proposal
  - Nov 96 (Palo Alto) test method agreed
  - Mar 97 (Dijon) call for proposals
  - Jul 97 (Sapporo) requirements analysis started
  - Nov 97 (Sydney) algorithm competition & selection
  - VM 1 (Mar 98), VM 2 (Aug 98), split to VM 3A and 3B Nov 98. Converged to VM4 and WD in Mar 99
  - Promotion to CD, FCD, FDIS as well as creation of different parts
- Current status: VM 8, FDIS

First steps of algorithm development

- November 1997 (Sydney)
  - about 100 participants
  - 24 candidate algorithms
  - All of them intensively tested
    - objective tests (quality metrics) ran on 22 test images at lossless and 6 different lossy bit rates (2, 1, 0.5, 0.25, 0.125, 0.0625 bpp)
    - subjective tests by 40 evaluators at the 3 lowest bit rates
  - selection WTCQ
  - VM established in March 98

JPEG2000 work plan

- Part I: A set of tools covering a good proportion of application requirements (20-80 rules)
- Other parts are also defined and planned for a further date
- Possible Amendment will be added to Part I
- Schedule for part I:

Elevation to FDIS:	08/00
Elevation to IS:	12/00

JPEG2000 work plan

- Part II: Extension tools to cover specific applications
- Part III: Motion JPEG2000
- Part IV: Conformance
- Part V: Reference software
- Part VI: Compound images file format
- Part VII: Technical Report
- Part VIII: ?

Status of existing implementations

Software status

- C implementation (SAIC / Univ. of Arizona / HP)
  - JPEG2000 Verification Model used for the development of the standard
- Java^{TM} implementation (EPFL, Ericsson, Canon)
  - Reference implementation of JPEG2000 in part V and publicly available
- C implementation (ImagePower / UBC)
  - Reference implementation of JPEG2000 in part V

JPEG2000 Features in Part I

- High compression efficiency
- Lossless colour transformations
- Lossy and lossless coding in one algorithm
- Embedded lossy to lossless coding
- Progressive by resolution, quality, position, ...
- Static and dynamic Region-of-Interest coding/decoding
- Error resilience
- Perceptual quality coding
- Multiple component image coding
- Tiling
- Palletized image coding
- Light file format (optional)
- ...

Some examples

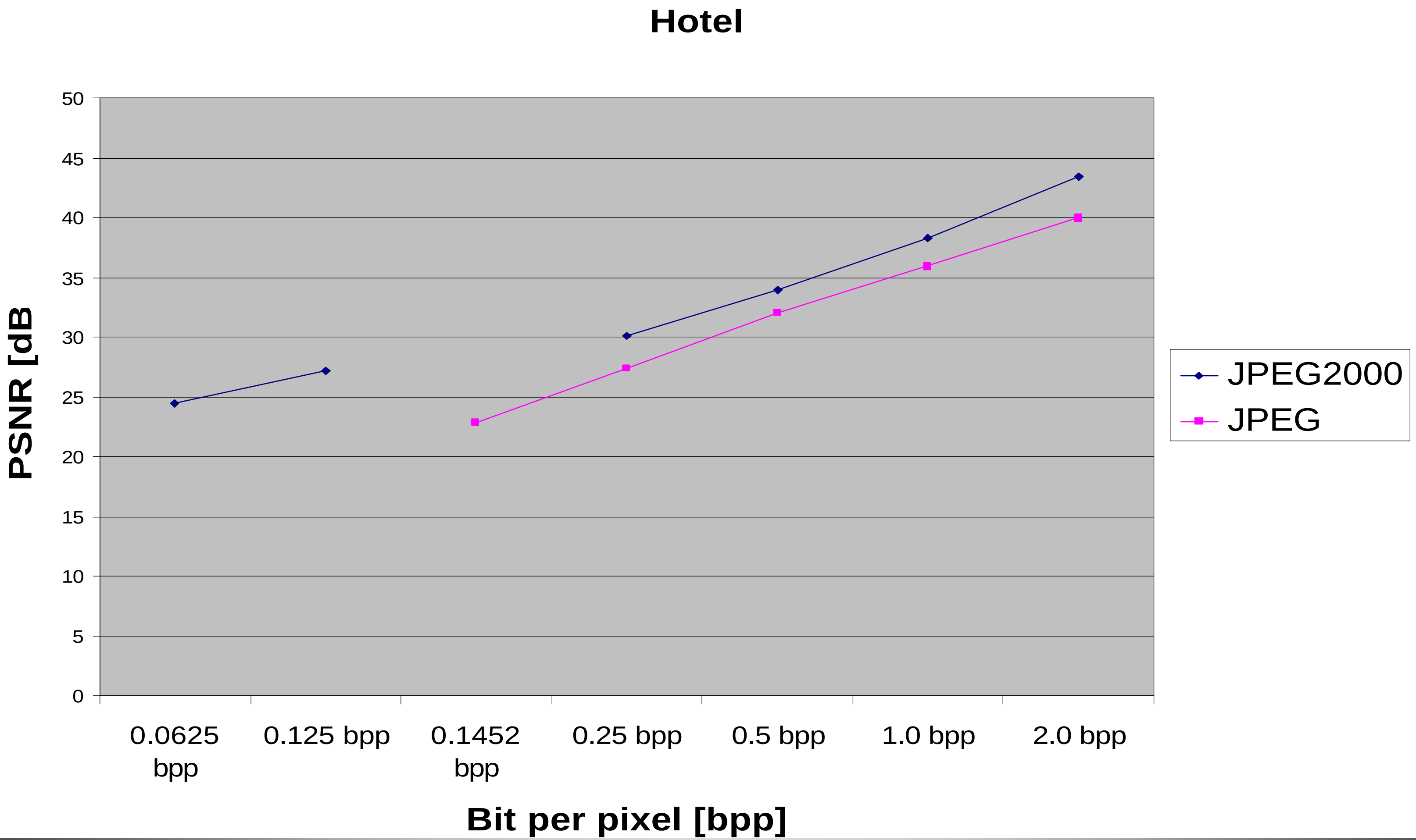
JPEG2000

versus

JPEG baseline

JPEG2000 vs. JPEG baseline

(cont'd)



JPEG at 0.125 bpp

JPEG2000 at 0.125 bpp

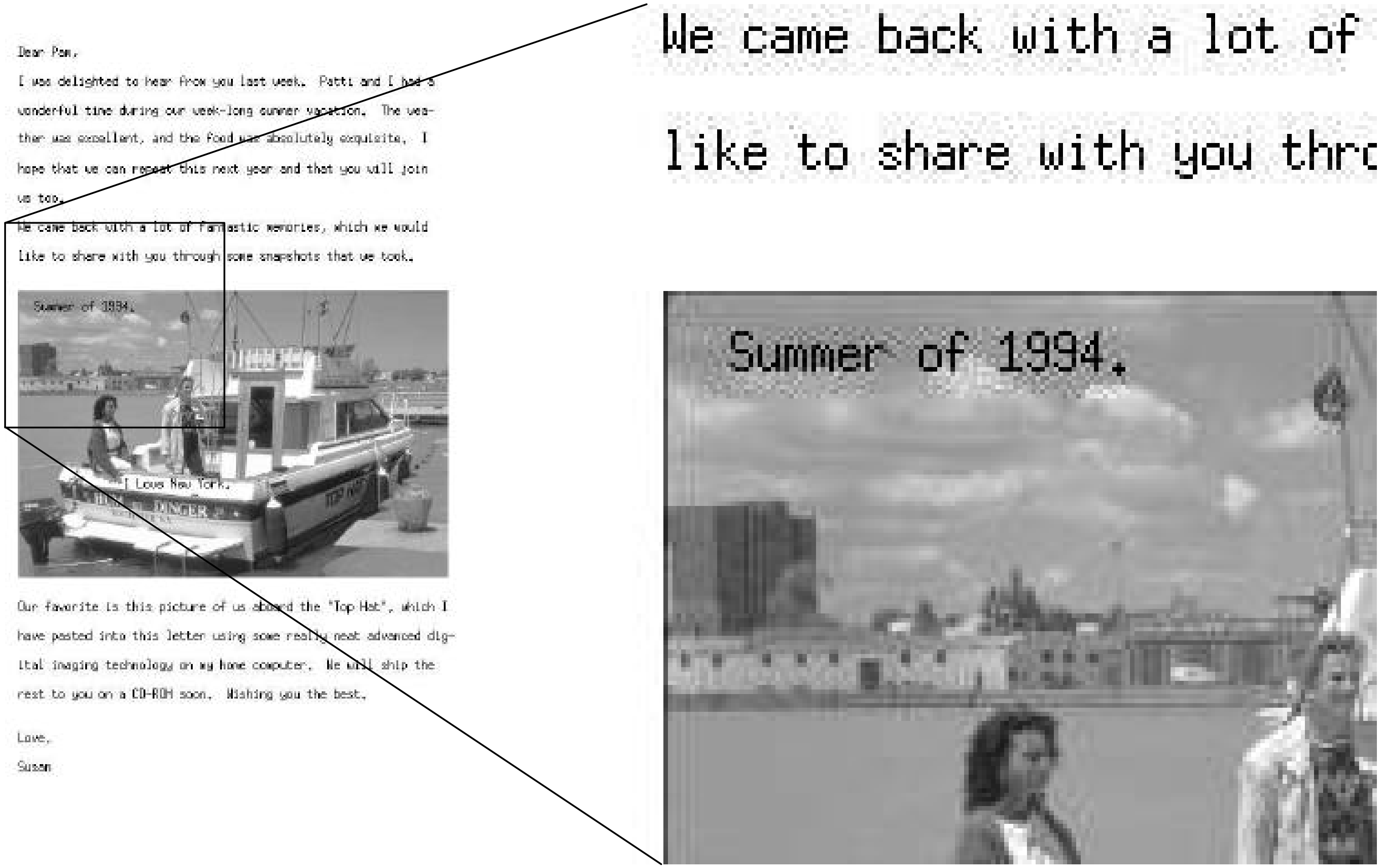
JPEG at 0.25 bpp

JPEG2000 at 0.25 bpp

JPEG at 0.5 bpp

JPEG2000 at 0.5 bpp

JPEG compound image 1.0 bpp


Dear Pam,

I was delighted to hear from you last week. Patti and I had a wonderful time during our week-long summer vacation. The weather was excellent, and the food was absolutely exquisite. I hope that we can repeat this next year and that you will join us too.

We came back with a lot of fantastic memories, which we would like to share with you through some snapshots that we took.

Summer of 1994.

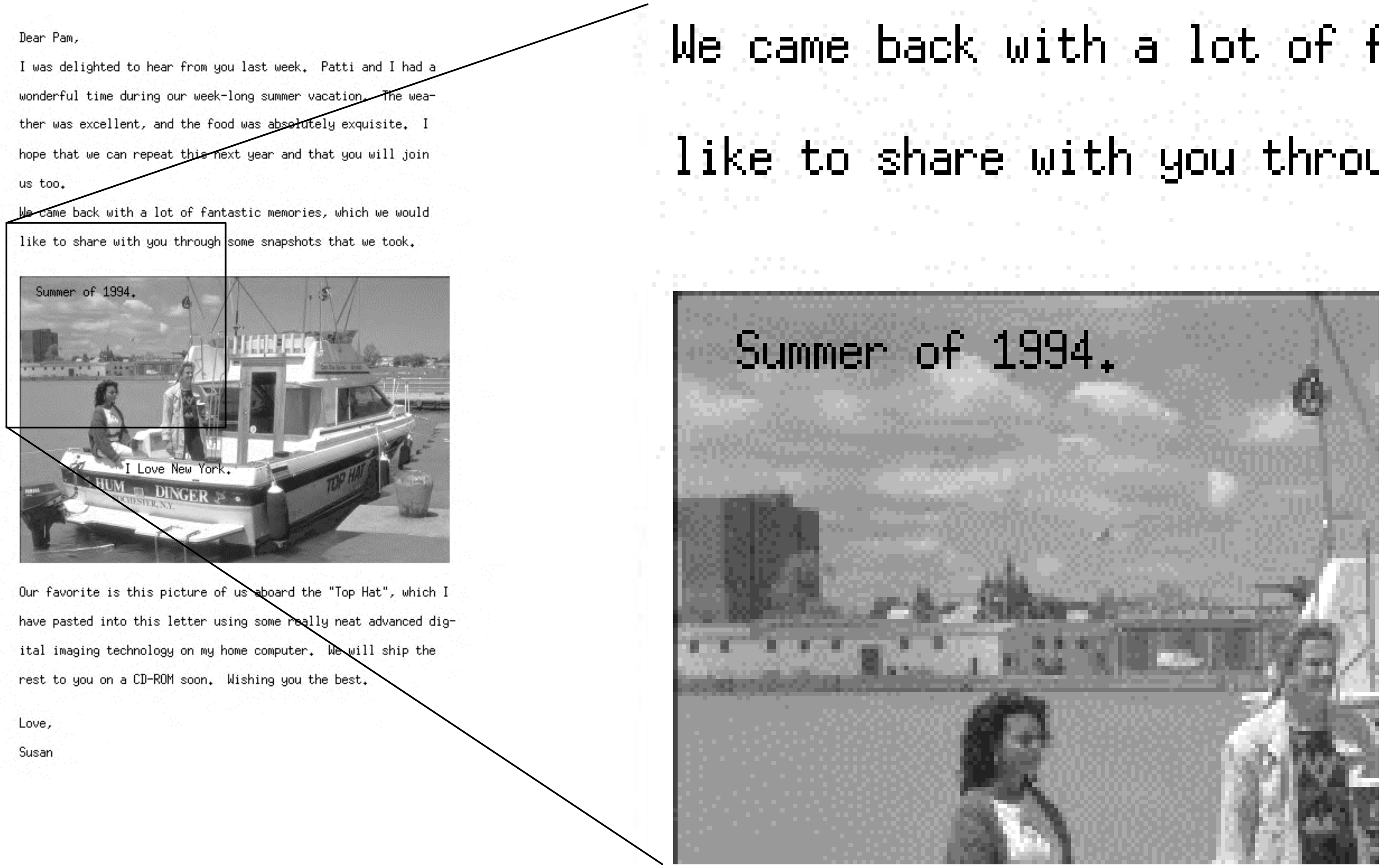
I Love New York.

Our favorite is this picture of us aboard the "Top Hat", which I have pasted into this letter using some really neat advanced digital imaging technology on my home computer. We will ship the rest to you on a CD-ROM soon. Wishing you the best.

Love,

Susan

JPEG2000 compound image 1.0 bpp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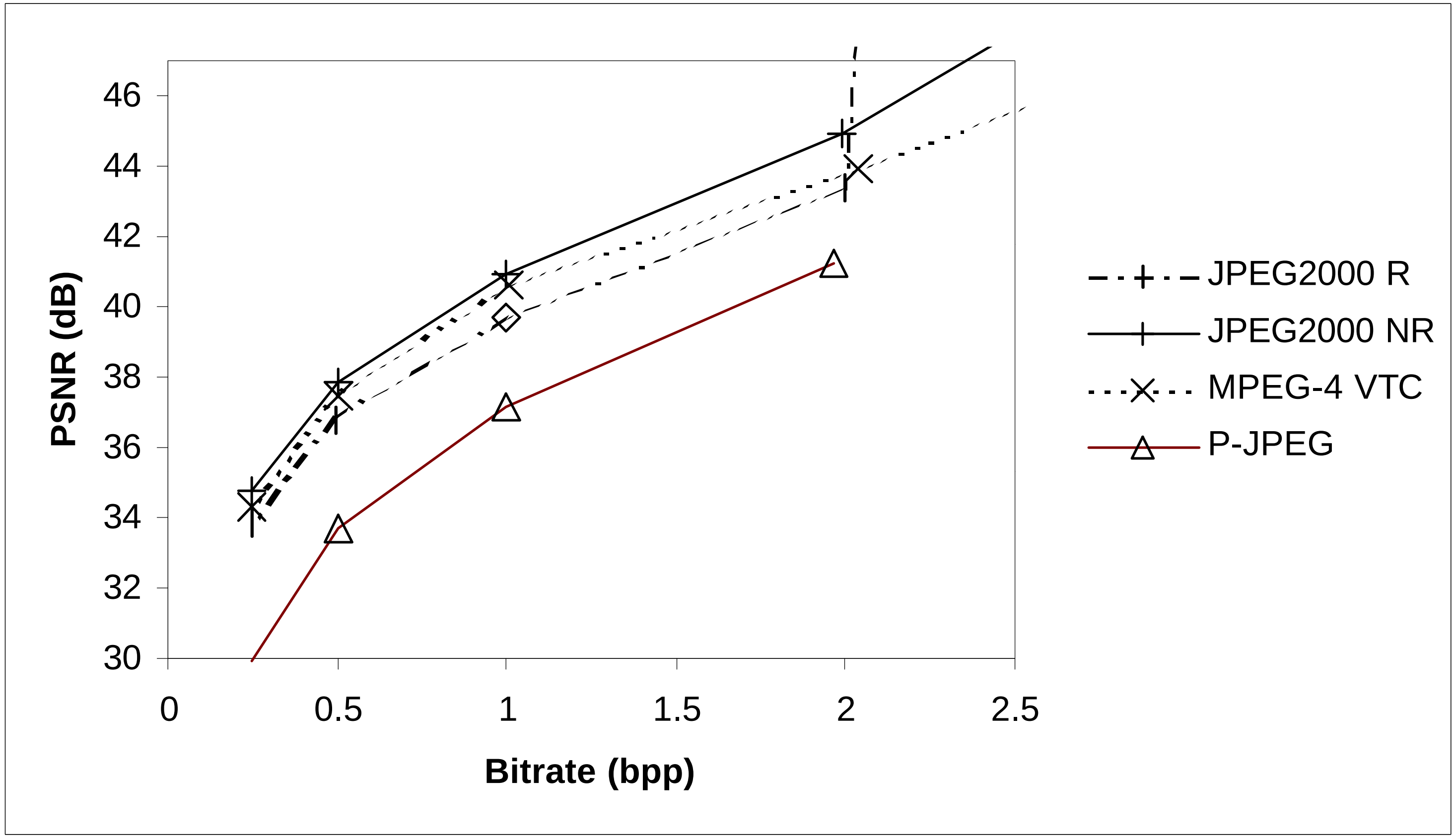
Love,

Susan

Major Differences between JPEG and JPEG2000

- New functionalities
  - ROI
  - Better error resiliency
  - More flexible progressive coding
  - ...
- Lossy to lossless in one system
- Better compression at low bit-rates
- Better at compound images and graphics (palletized)

JPEG2000 MPEG-4 VTC and JPEG



Some lossless compression results

Image	JPEG lossless	JPEG-LS	JPEG2000
Lena (24bpp)	14.75 (1.627 : 1)	13.56 (1.770 : 1)	13.54 (1.773 : 1)
Cmpnd1 (8bpp)	2.48 (3.226 : 1)	1.24 (6.452 : 1)	2.12 (3.774 : 1)

Comparison of various algorithms from a functionality point of view

lgorithm	Lossless comp.	Lossy comp.	Embedded bitstream	Region of interest	Arbitrary shaped object	Error resilient	Scalable	Comple -xity	Rando m access	Generic
'EG	(+)	++	-	-	-	-	(+)	++(+)	+	+
lPEG-4 VTC	-	+++	+++	+	++	++	++	+	-	++
'EG-LS	++++	+	+	-	-	-	-	++	-	+
'EG2000	+++	+++	+++	++	-	++	++	+	++	+++

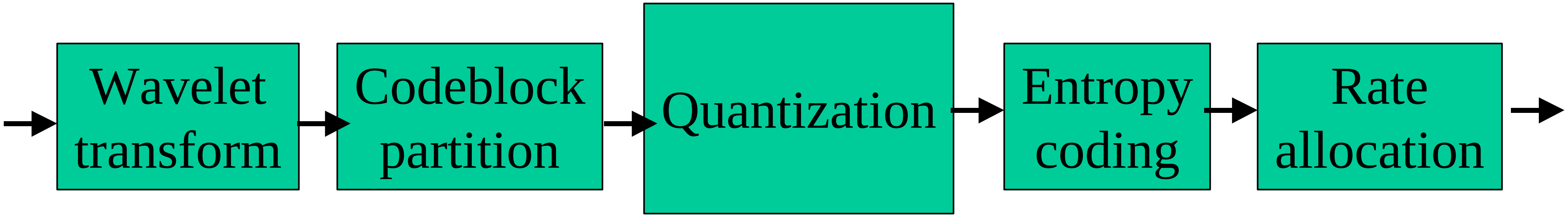
More in depth comparisons between JPEG2000 versus other standards

- « JPEG 2000 still image coding versus other standards », D. Santa-Cruz, T. Ebrahimi, J. Askelöf, M. Larsson and Ch. Christopoulos, in Proc. of SPIE, Vol. 4115
- « A study of JPEG 2000 still image coding versus other standards », D. Santa-Cruz, T. Ebrahimi, in Proc. of the X European Signal Processing Conference (EUSIPCO), Tampere, Finland, September 5-8, 2000
- « An analytical study of JPEG 2000 functionalities », D. Santa-Cruz, T. Ebrahimi, in Proc. of the IEEE International Conference on Image Processing (ICIP), Vancouver, Canada, September 10-13, 2000

JPEG2000

Algorithm description

JPEG2000: Basic encoding scheme



Embedded Block Coding with Optimized Truncation (EBCOT)

- Each subband is partitioned into a set of blocks
- All blocks within a subband have the same size (possible exception for the blocks at the image boundaries)
- Blocks are encoded independently
- Post-processing operation determines the extent to which each block's bitstream should be truncated
- Final bitstream is composed of a collection of “layers”

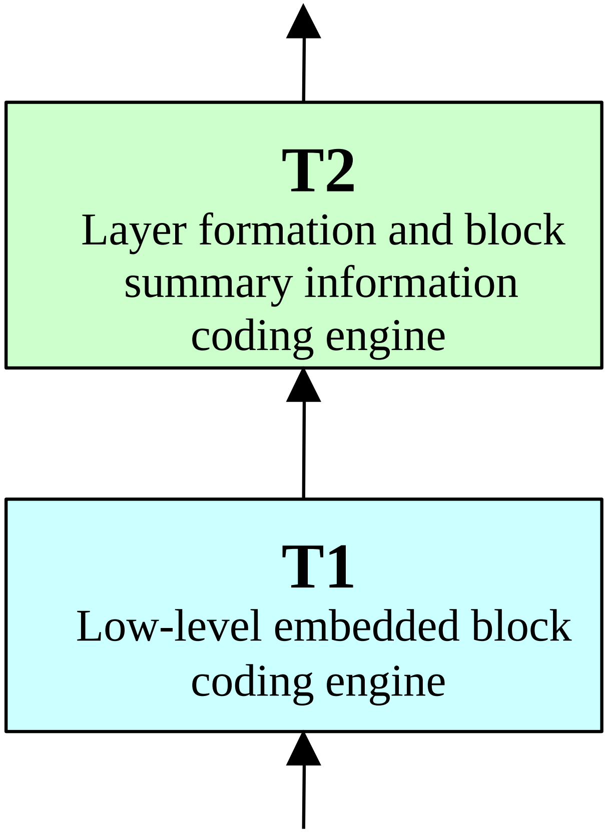
Why block coding?

- exploit local variations in the statistics of the image from block to block
- provide support for applications requiring random access to the image
- reduce memory consumption in hardware implementations of the compression or decompression engine
- Allow for parallel implementation

EBCOT coding operations

- **T2**: layered bitstream formation

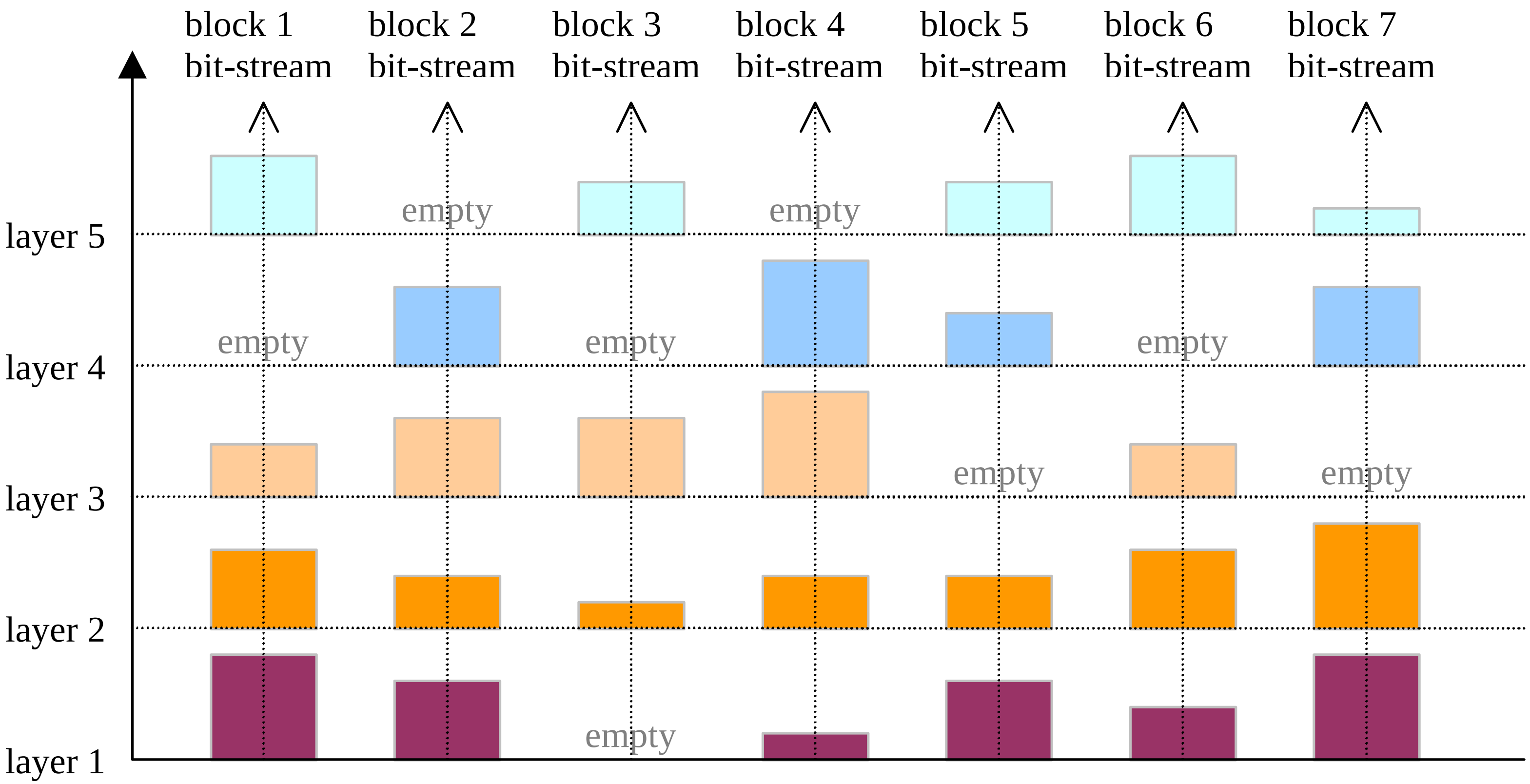
- **T1**: generation of embedded block bit-streams



EBCOT: layered bitstream formation

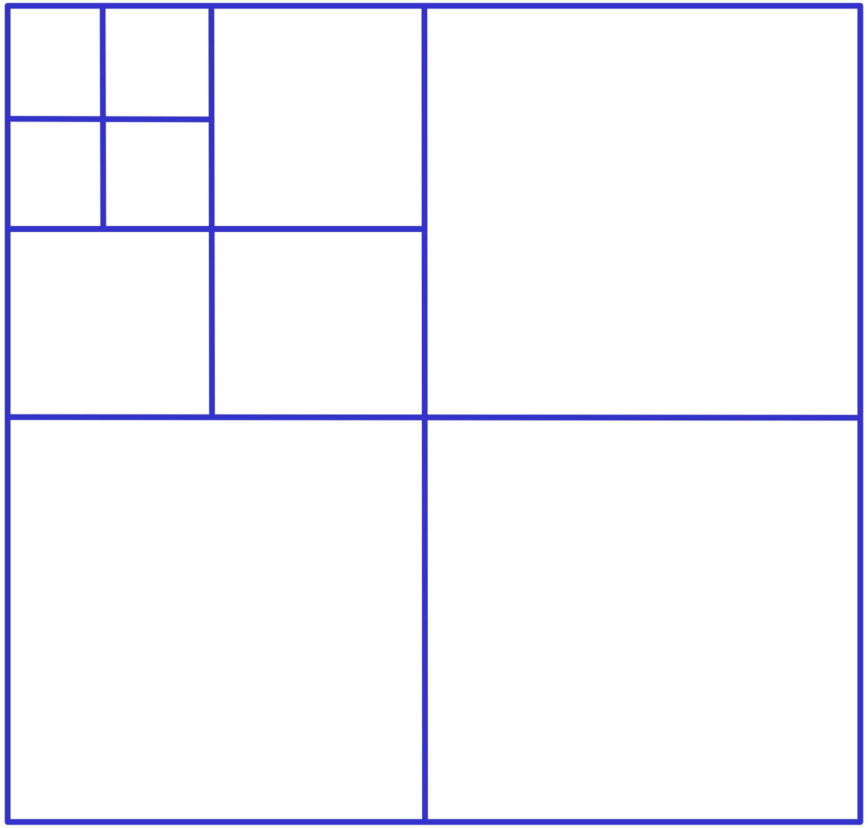
- Each bitstream is organized as a succession of layers
- Each layer contains additional contributions from each block (some contributions might be empty)
- Block truncation points associated with each layer are optimal in the rate distortion sense
- Rate distortion optimization can be performed but it does not need to be standardized

EBCOT layered formation



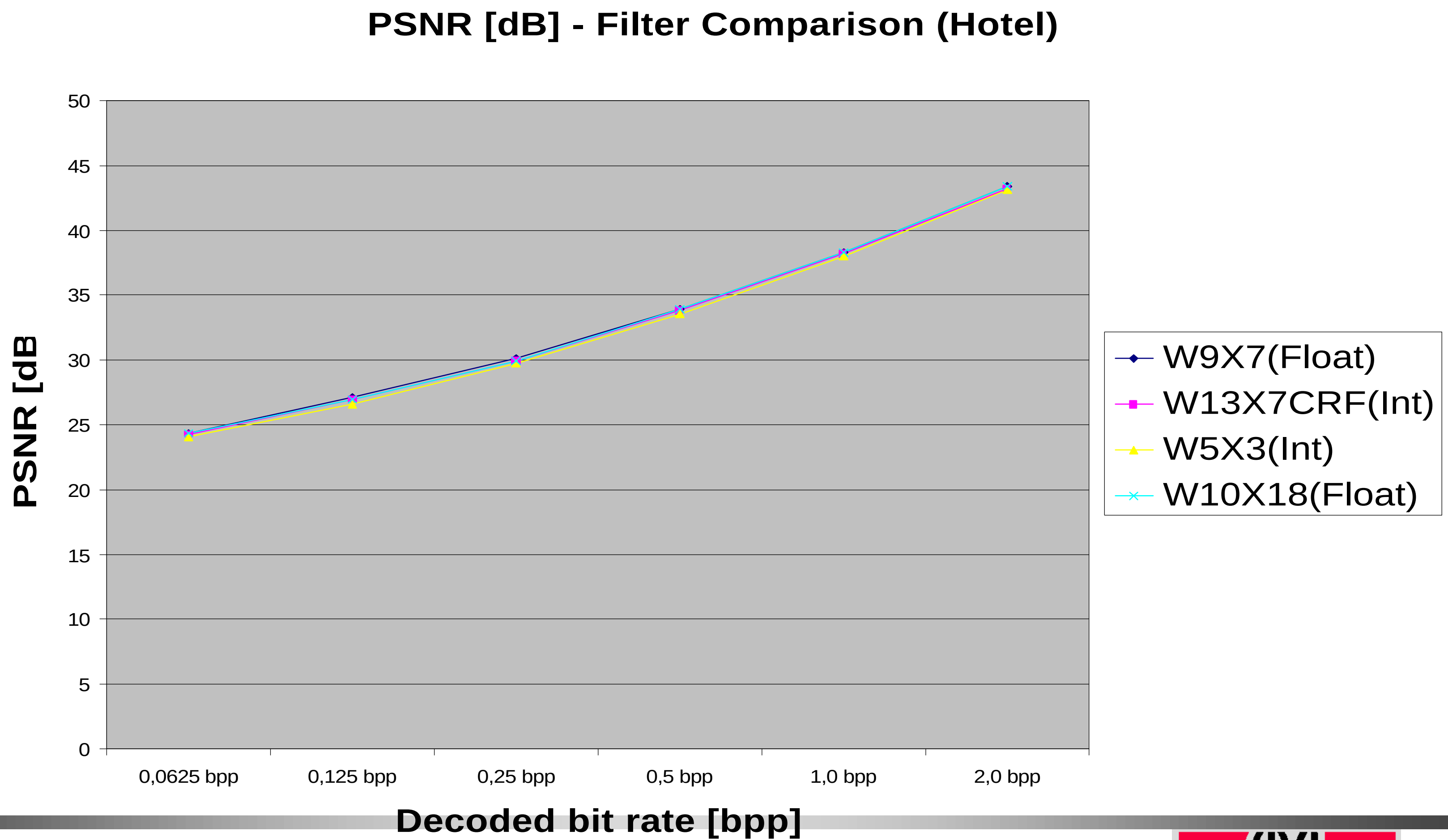
Wavelet Transform

Dyadic decomposition

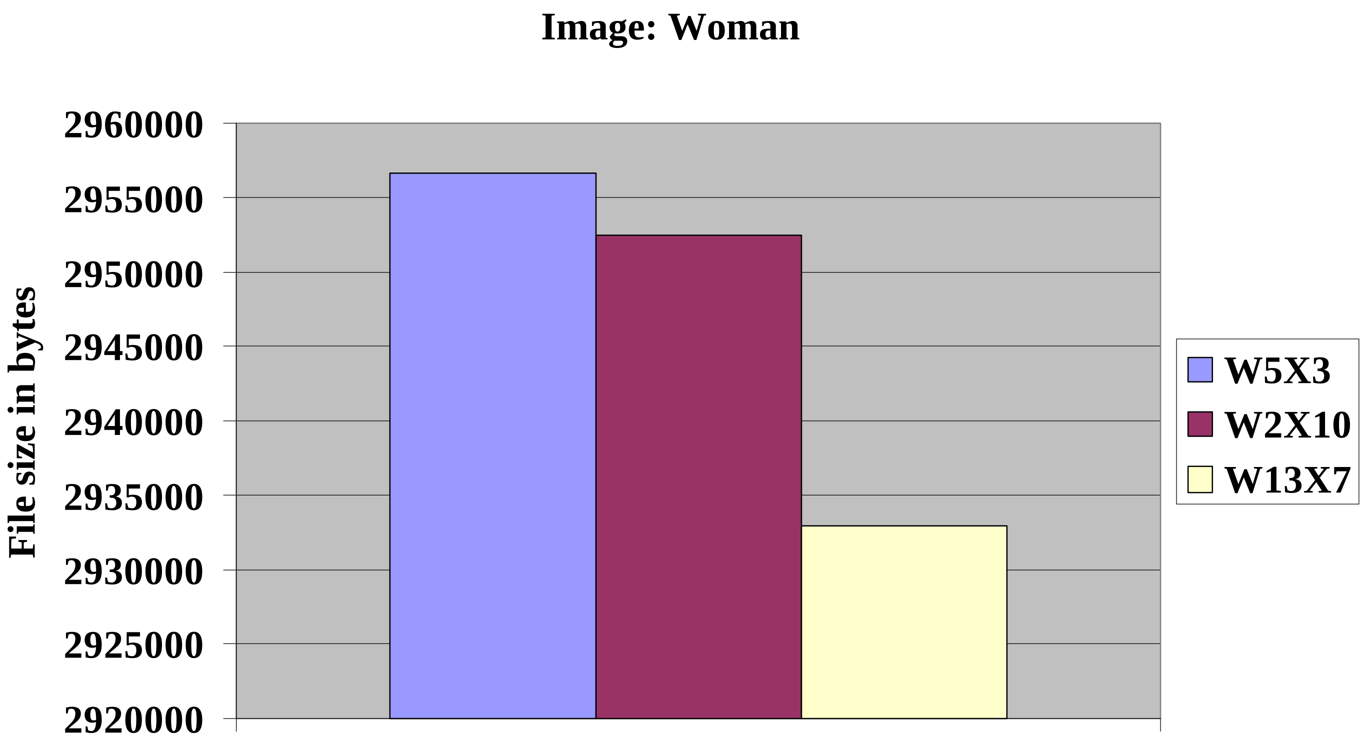


- Two filters supported
  - W9x7 (Floating point) for lossy coding
  - W5x3 (Integer) for lossless coding
- Only dyadic decomposition supported

Some results for different filters

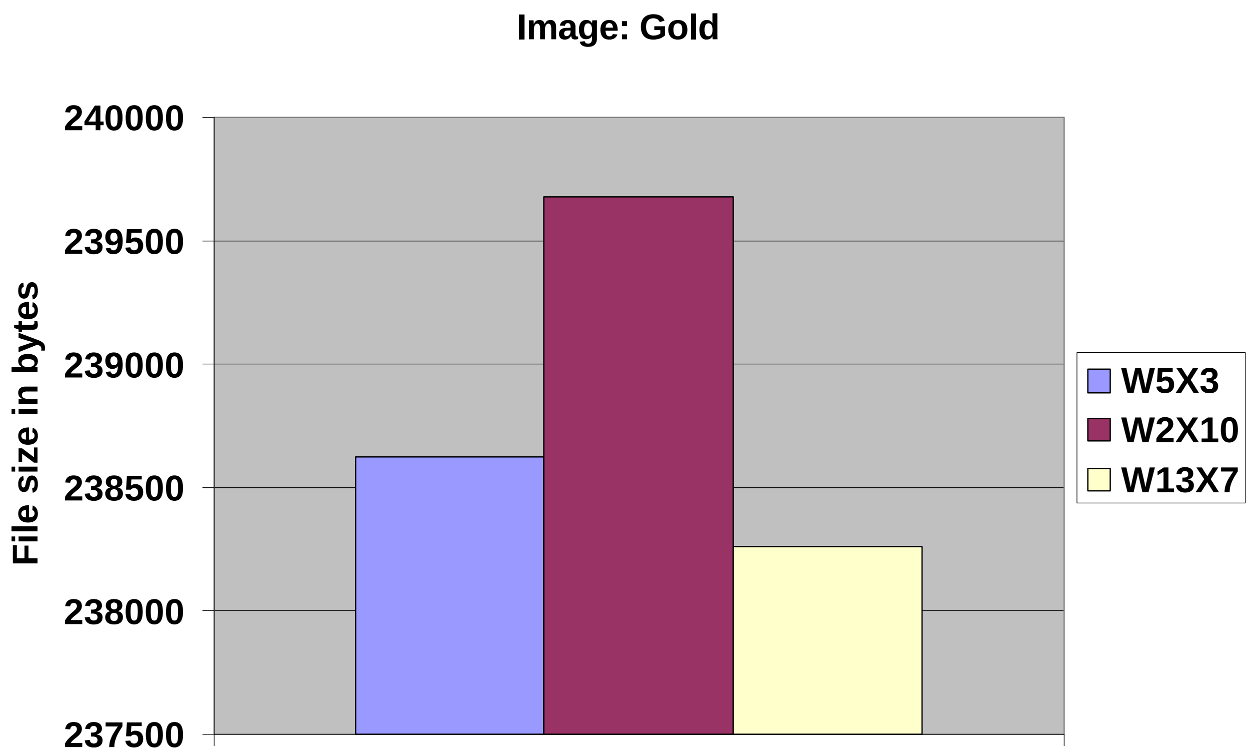


Some results for lossless coding



Some results for lossless coding

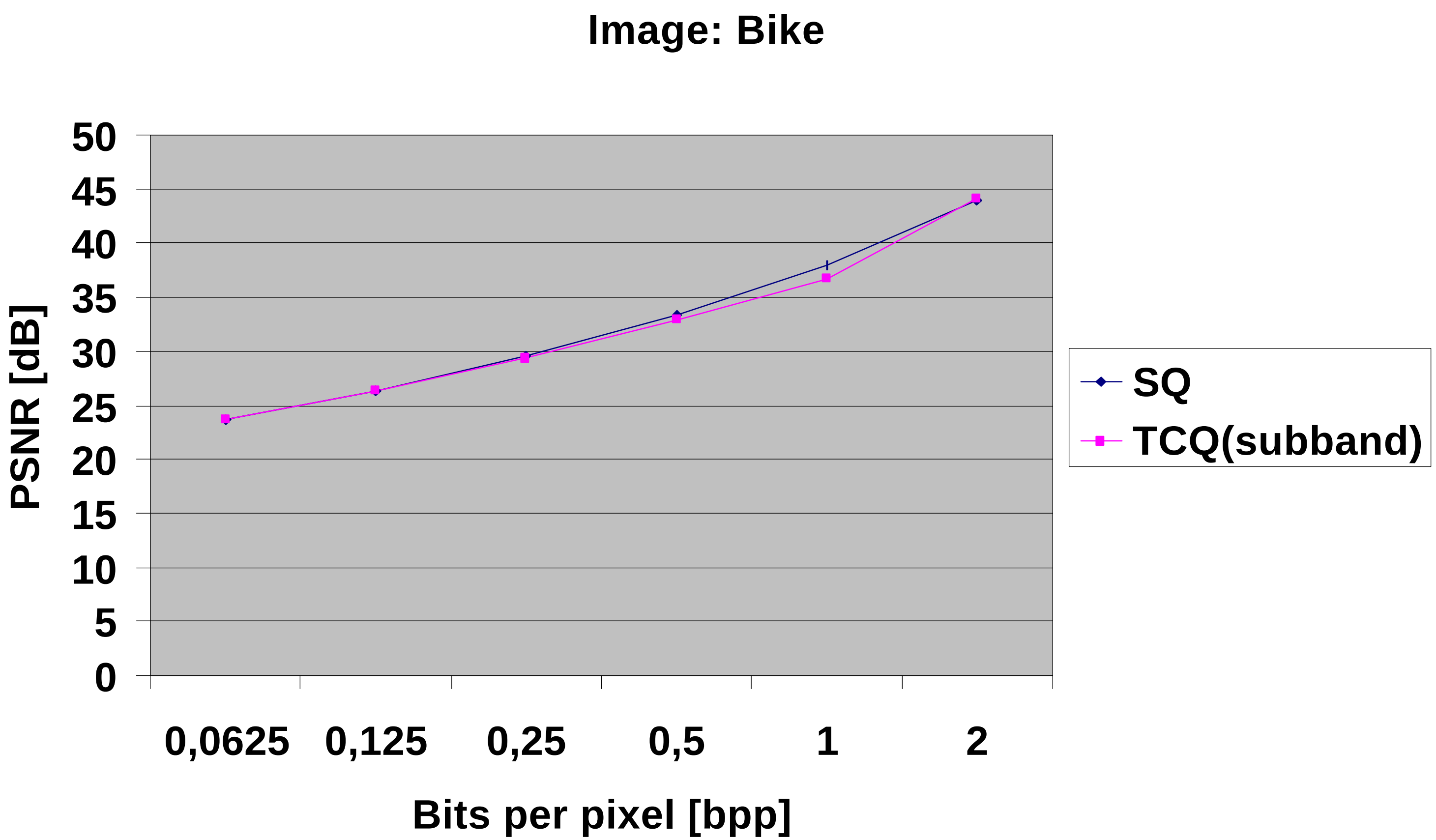
Some results for lossless coding



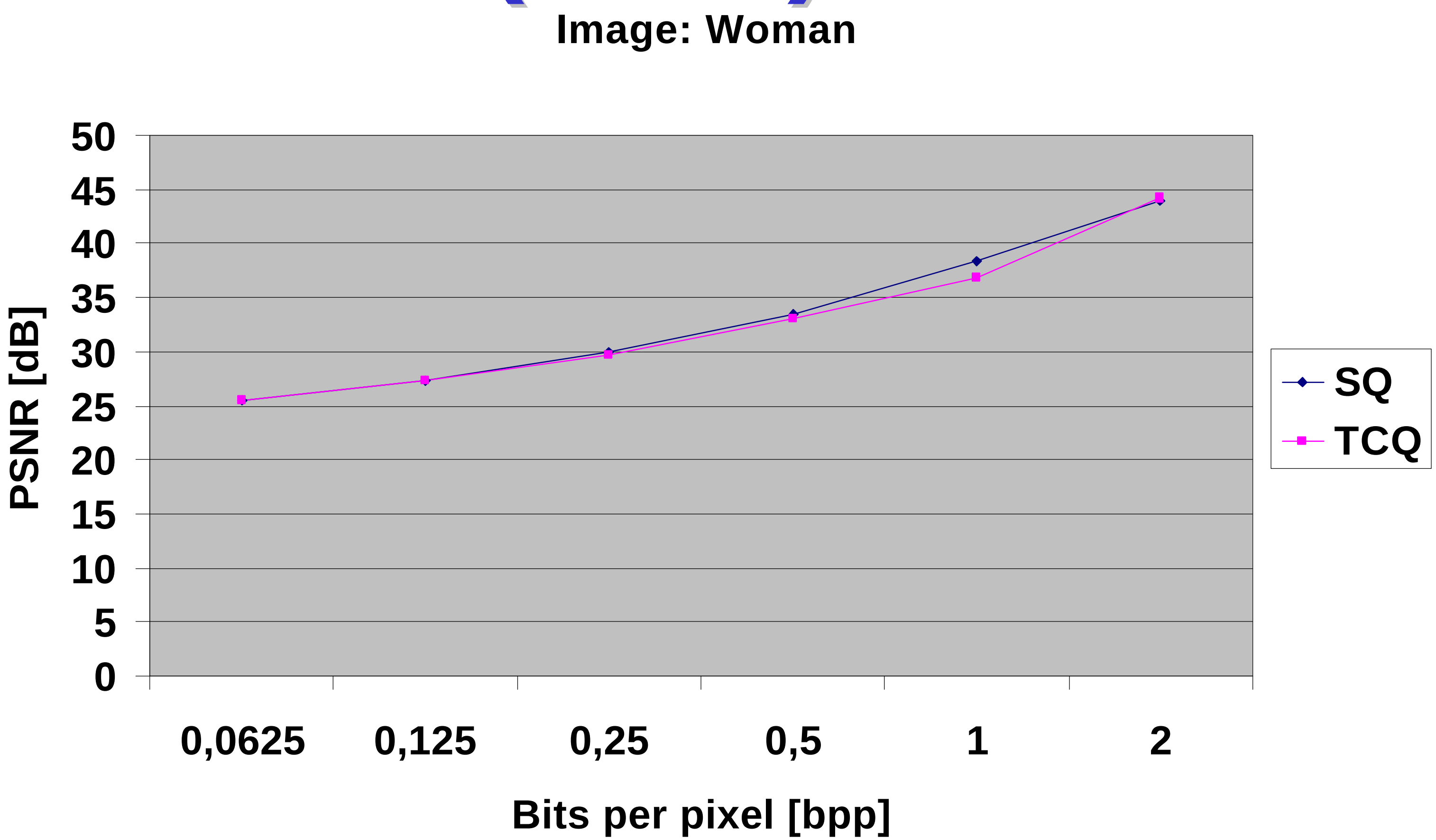
Quantization

- **Explicit**
  - Define a specific quantization step for each subband
  - Smaller quantization steps for lower resolution subbands
- **Implicit**
  - Quantization steps derived from LL subband quantization steps
  - Smaller quantization steps for lower resolution subbands
- **Reversible**
  - No quantization but pure bit plane coding of transform coefficients
- **Possibility of visual weighting**
  - Fixed visual weighting
  - Visual progressive coding (VIP)

Some results: SQ vs. TCQ



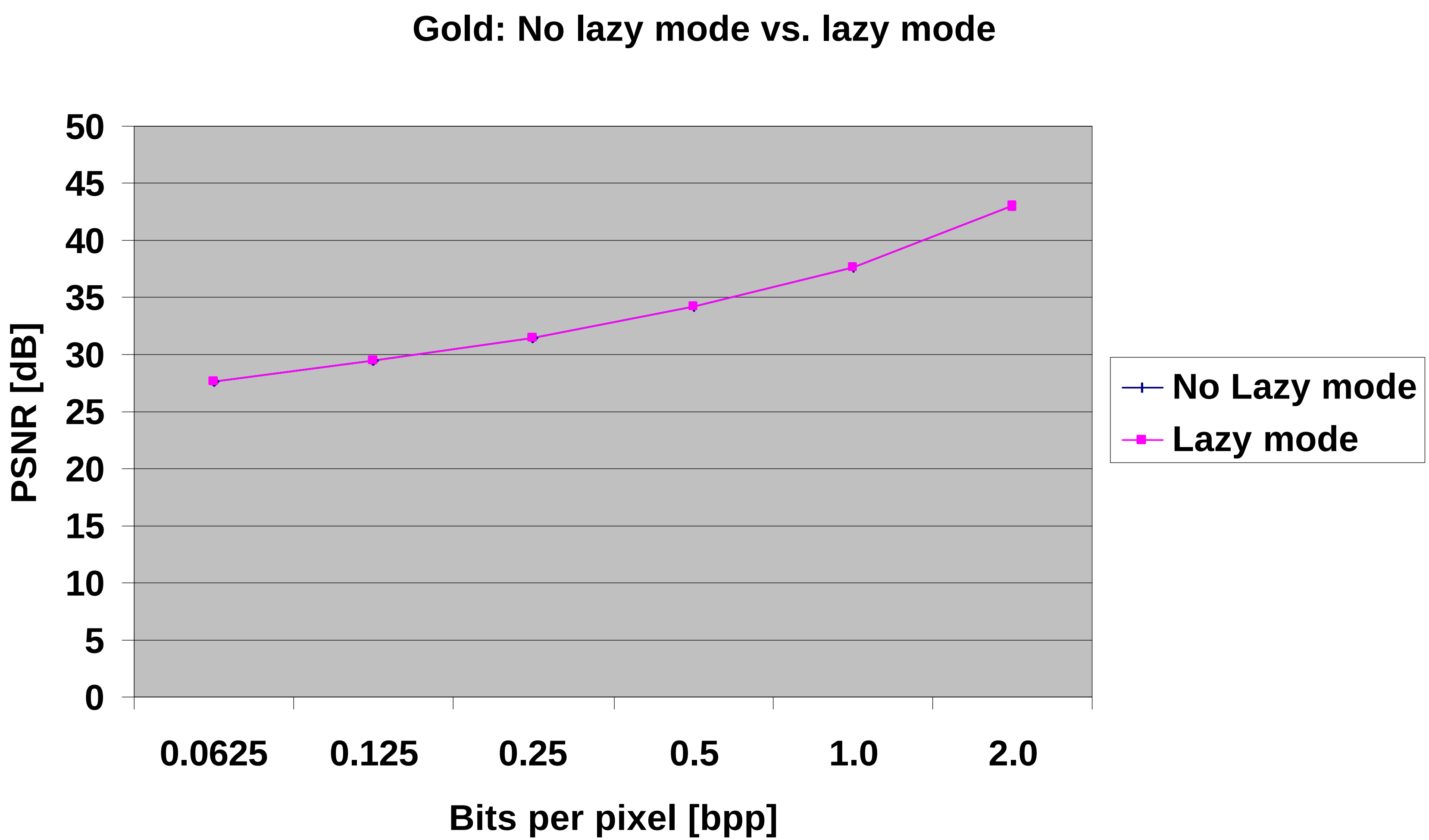
Some results: SQ vs. TCQ (cont.)



LAZY CODING MODE

- Not all bitplanes need to be encoded by arithmetic coding
- Some bits are saved as raw bits
- This increases speed without sacrificing performance

Lazy mode: Image "Gold"



No lazy mode: 0.0625 bpp

Lazy mode: 0.0625 bpp

No lazy mode: 0.25 bpp

lazy mode: 0.25 bpp

Multi-component imagery

- up to 256 components
- arbitrary dimensions/bit depths for each component
- reversible & non-reversible component color transforms

Reversible color transformation:
making lossless color coding possible

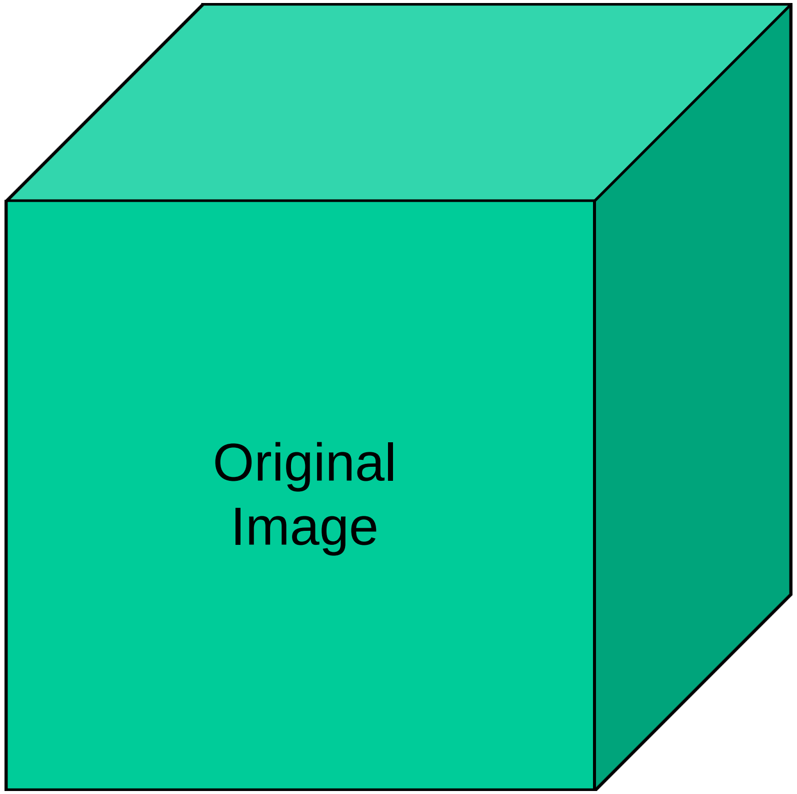
$$Yr = \left\lfloor \frac{R + 2*G + B}{4} \right\rfloor \qquad G = Yr - \left(\frac{Ur + Vr}{4}\right)$$

$$Ur = R - G \qquad R = Ur + G$$

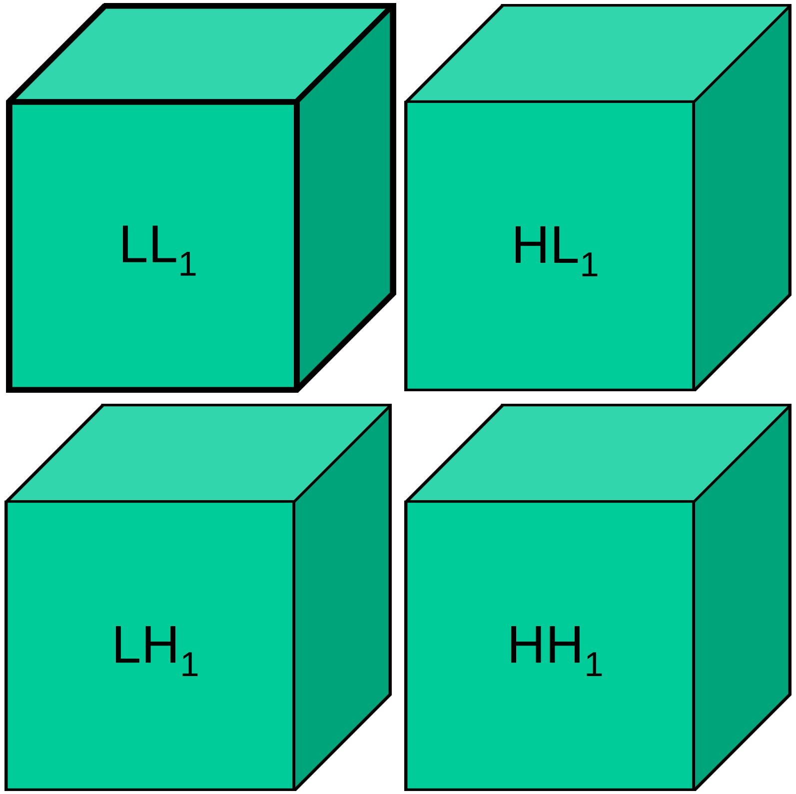
$$Vr = B - G \qquad B = Vr + G$$

All components must have identical subsampling parameters and same depth before transformation

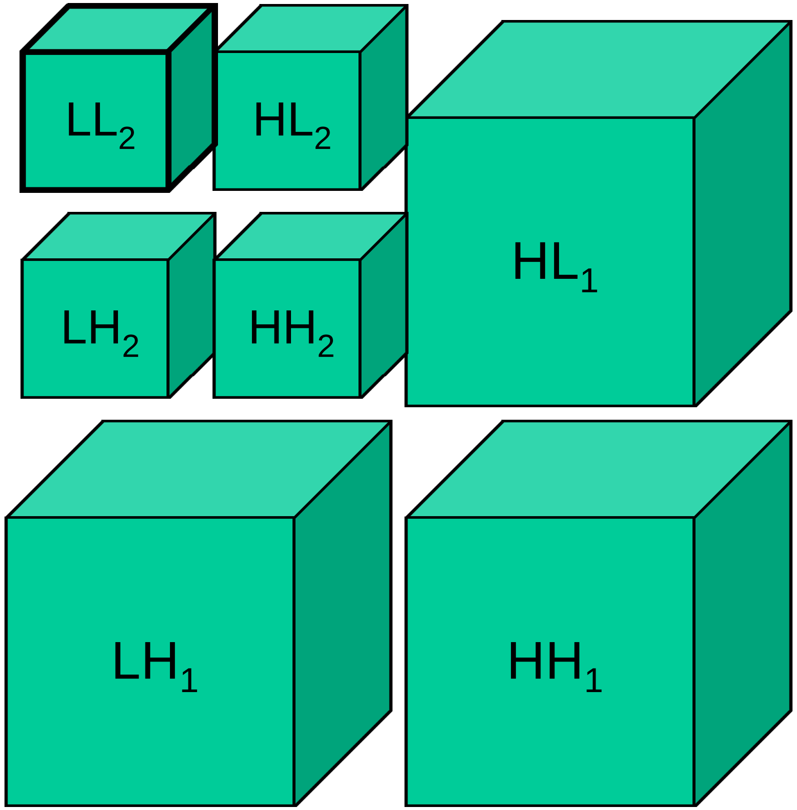
Multiresolution decomposition

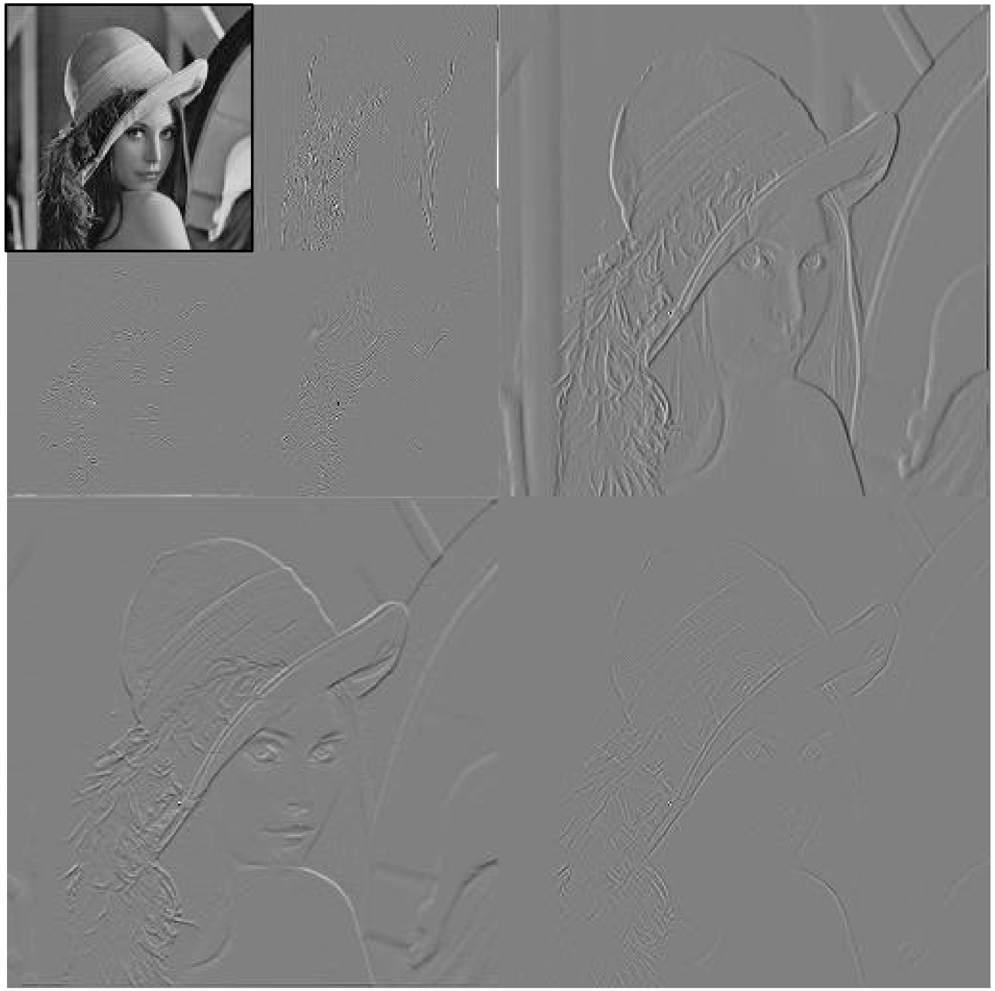


Multiresolution decomposition

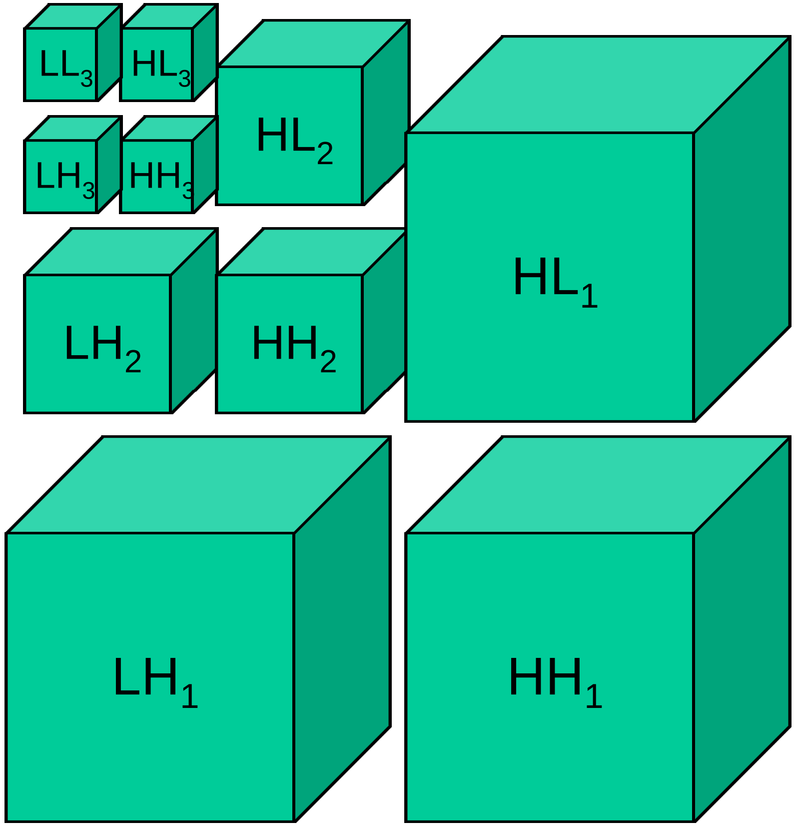


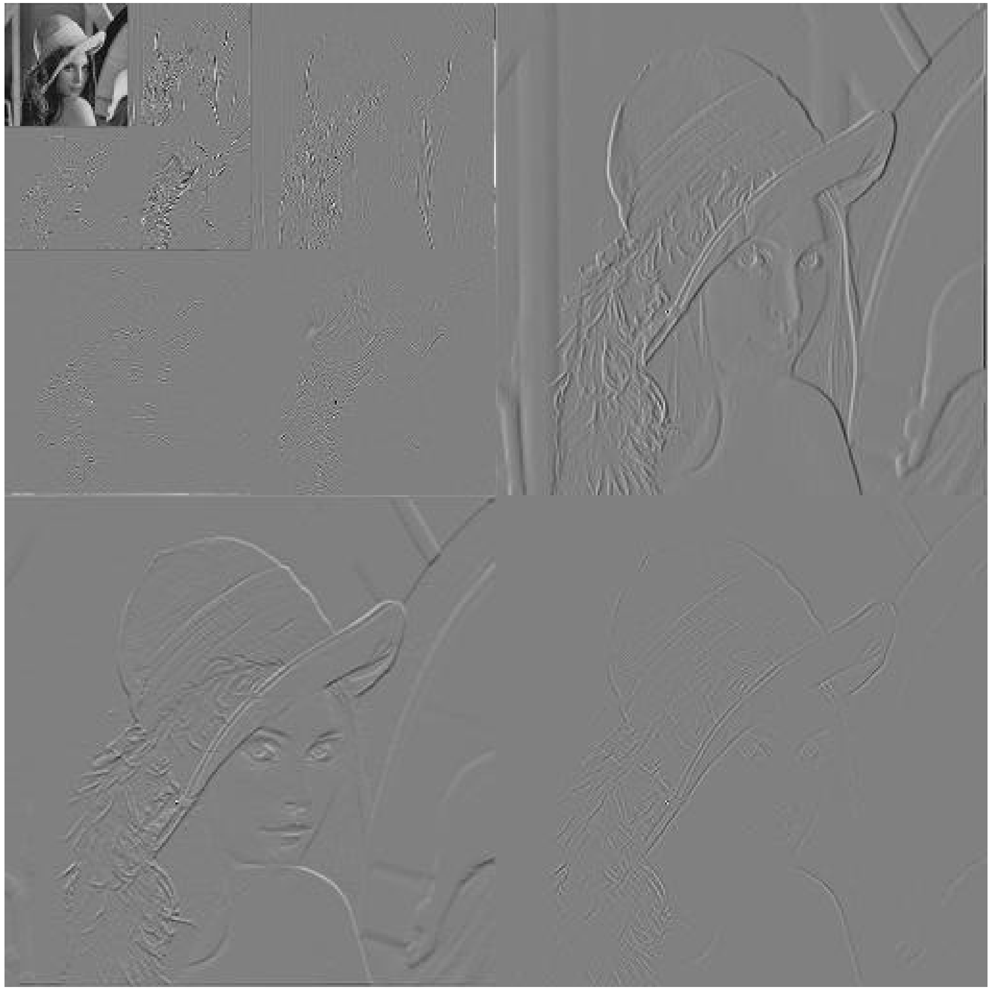
Multiresolution decomposition





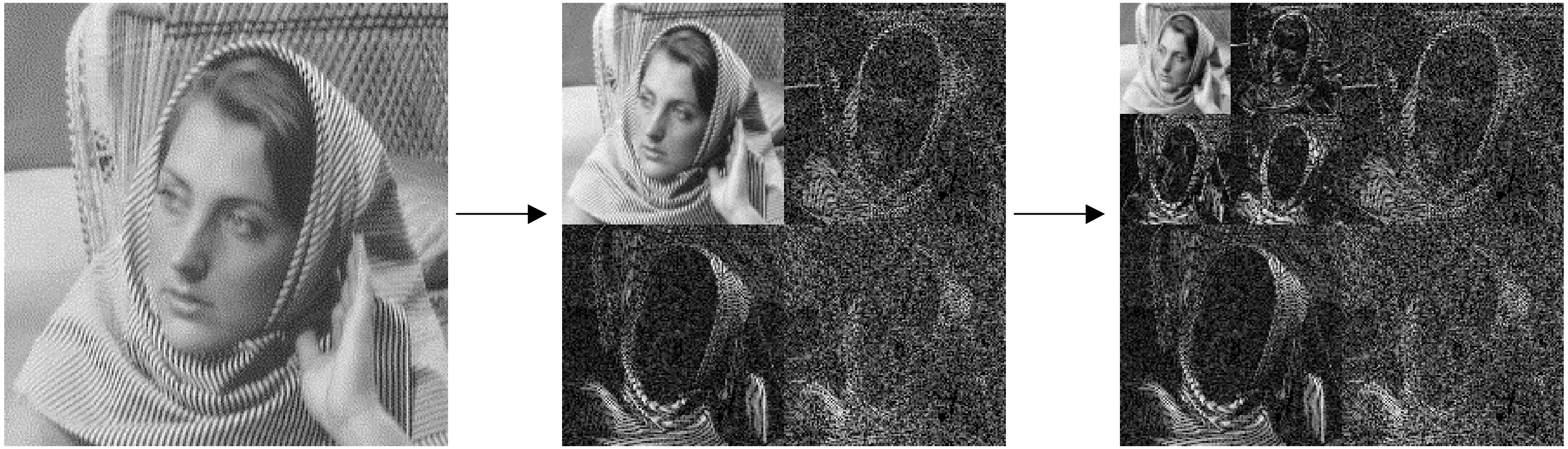
Multiresolution decomposition





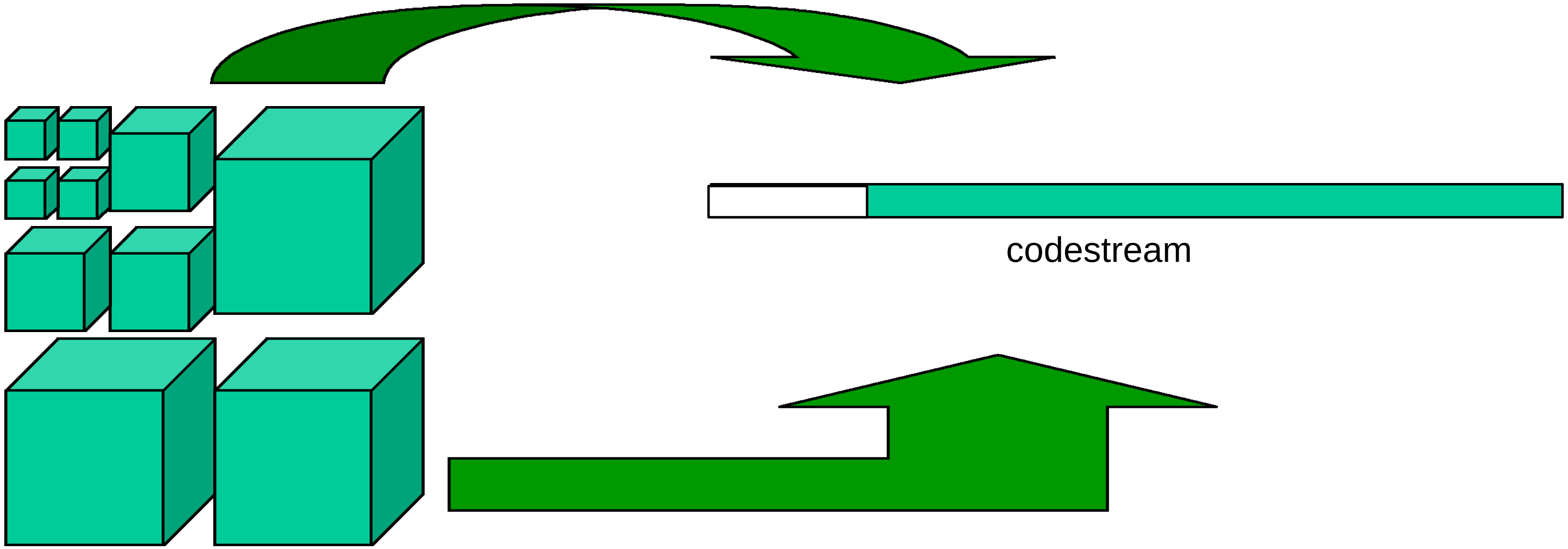
Multiresolution decomposition

Example of dyadic decomposition
into subbands

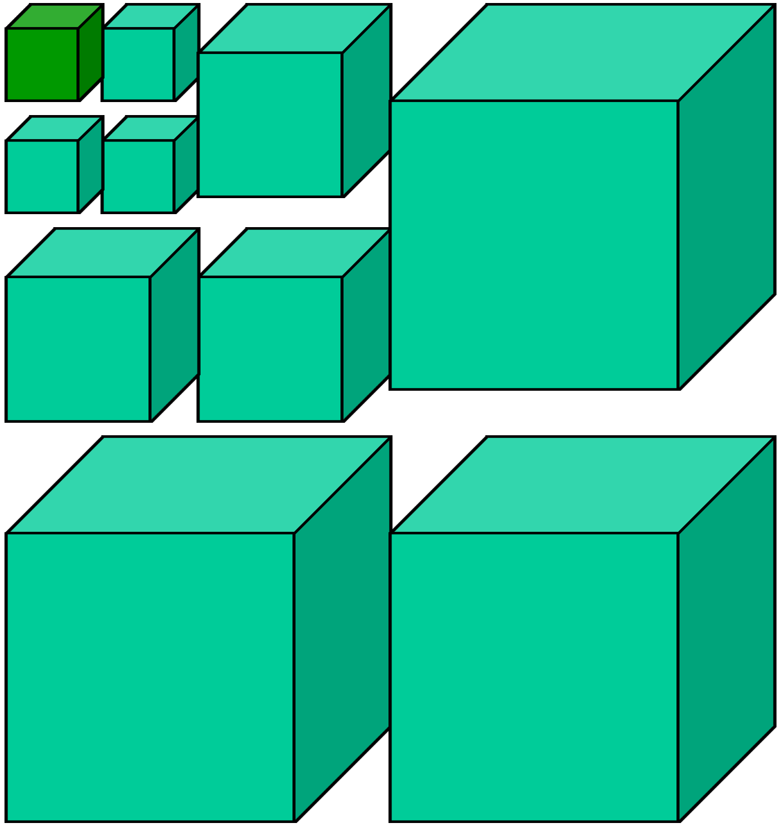


JPEG2000: Scalability

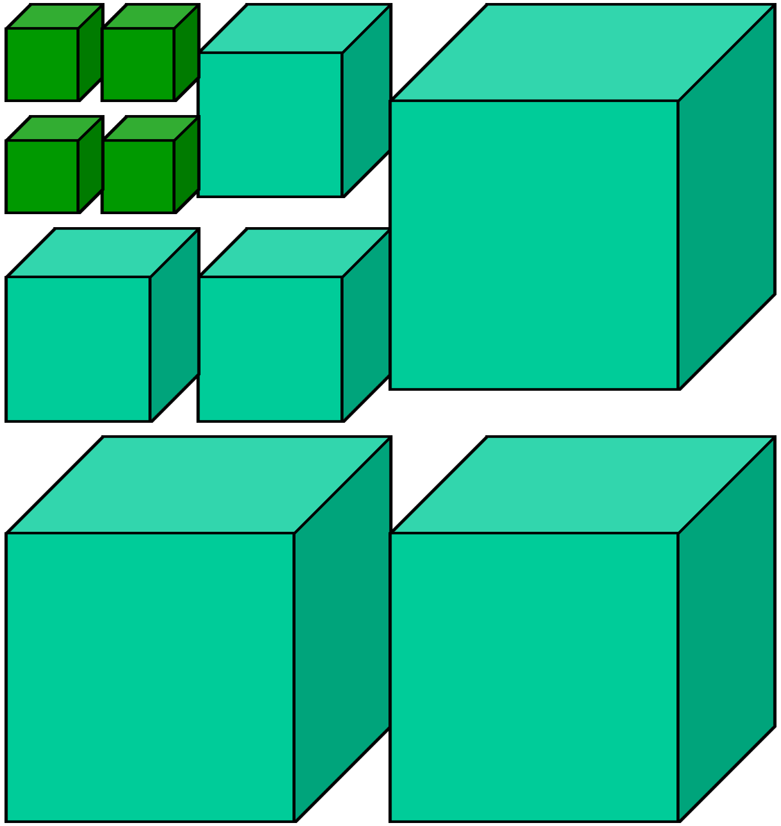
– Different modes are realized depending on the way information is written into the codestream



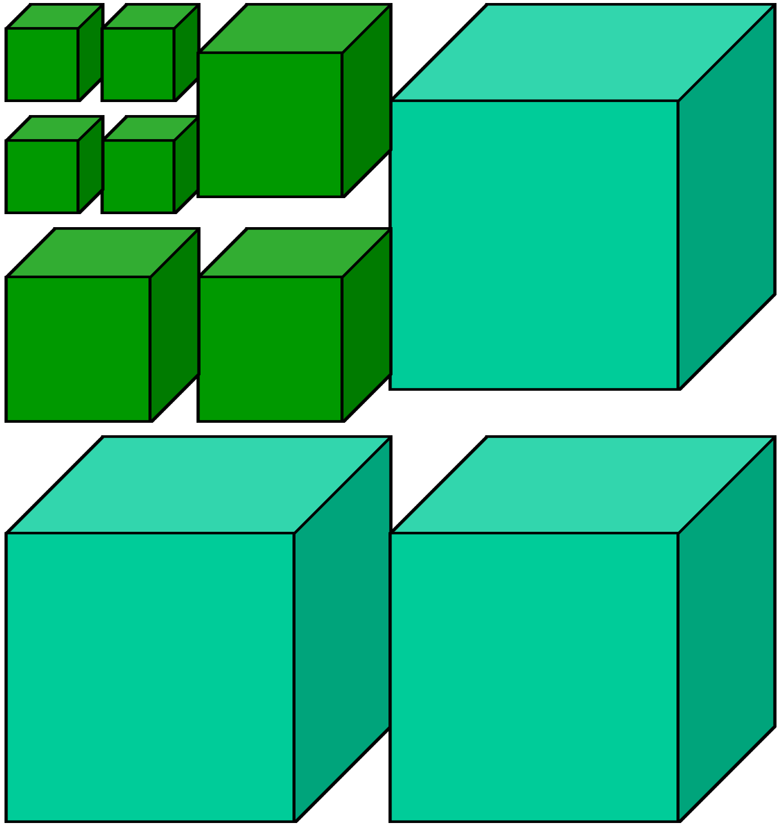
Scalability - Progressive By Resolution



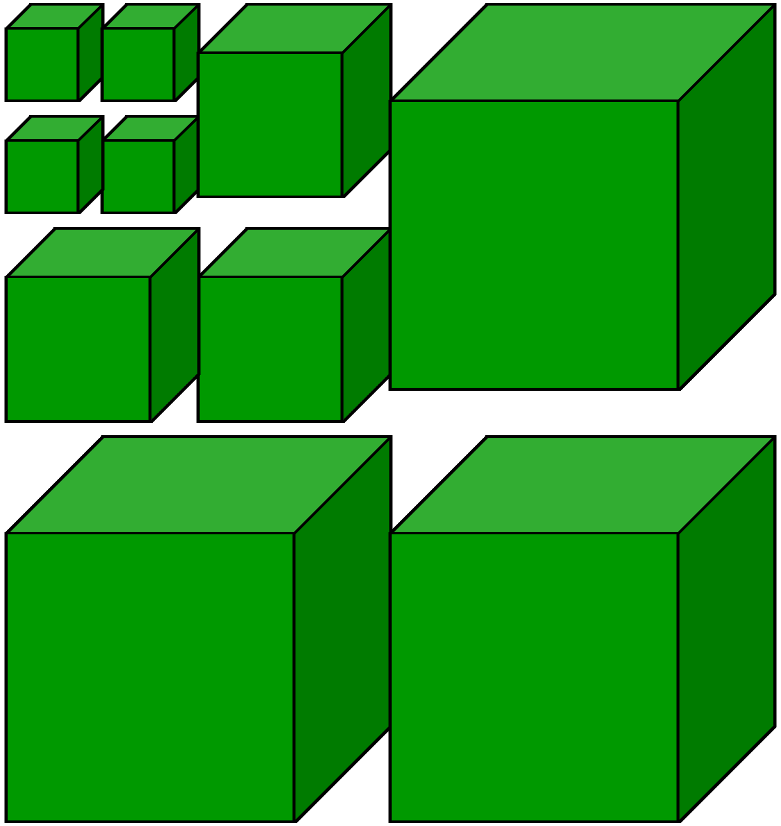
Scalability - Progressive By Resolution



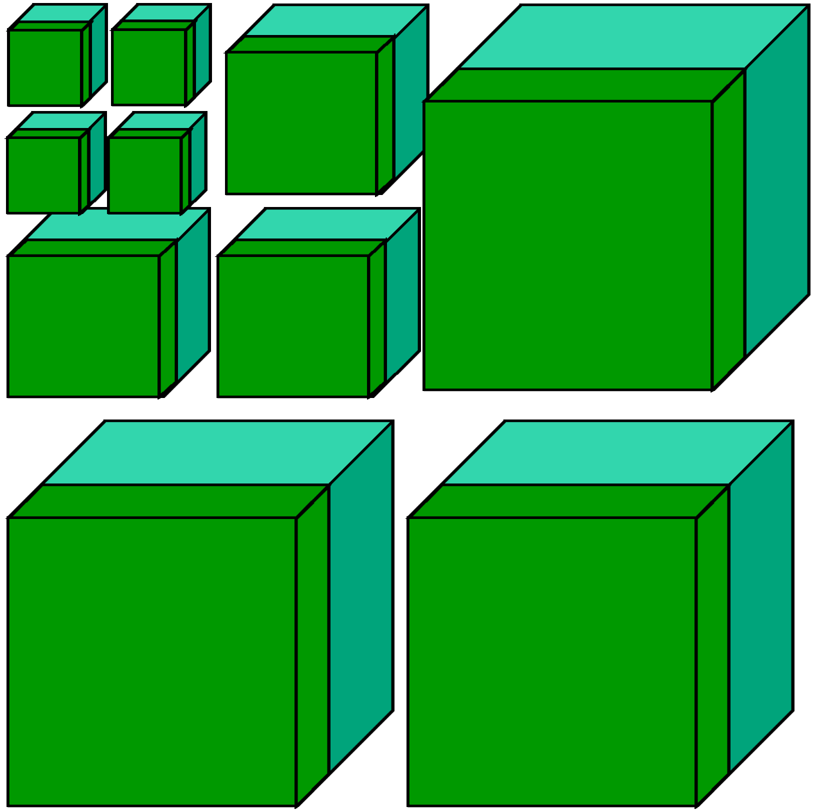
Scalability - Progressive By Resolution



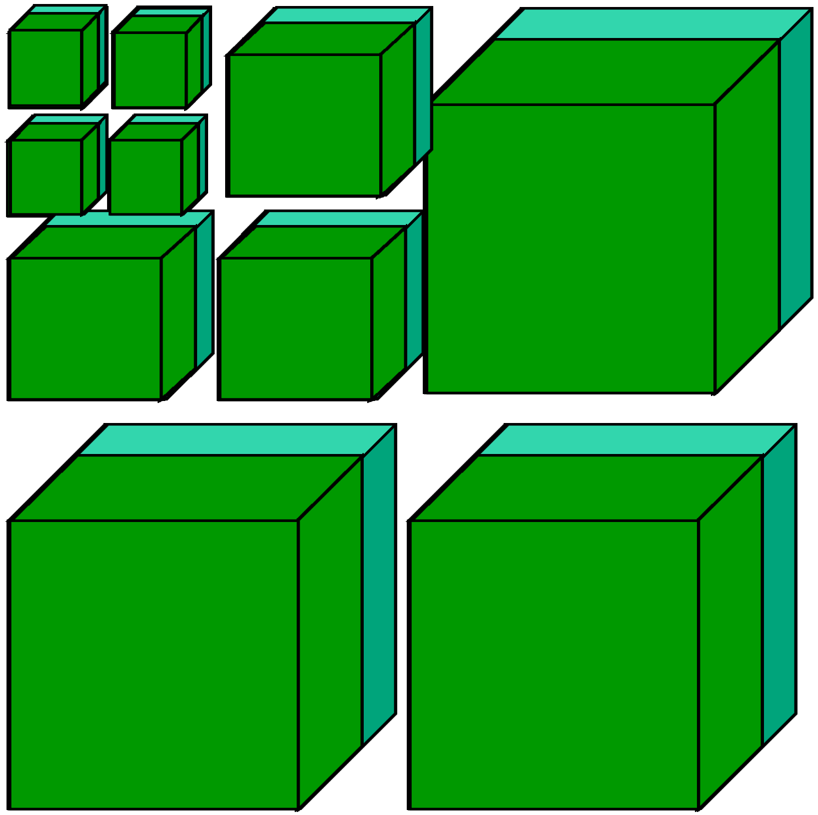
Scalability - Progressive By Resolution



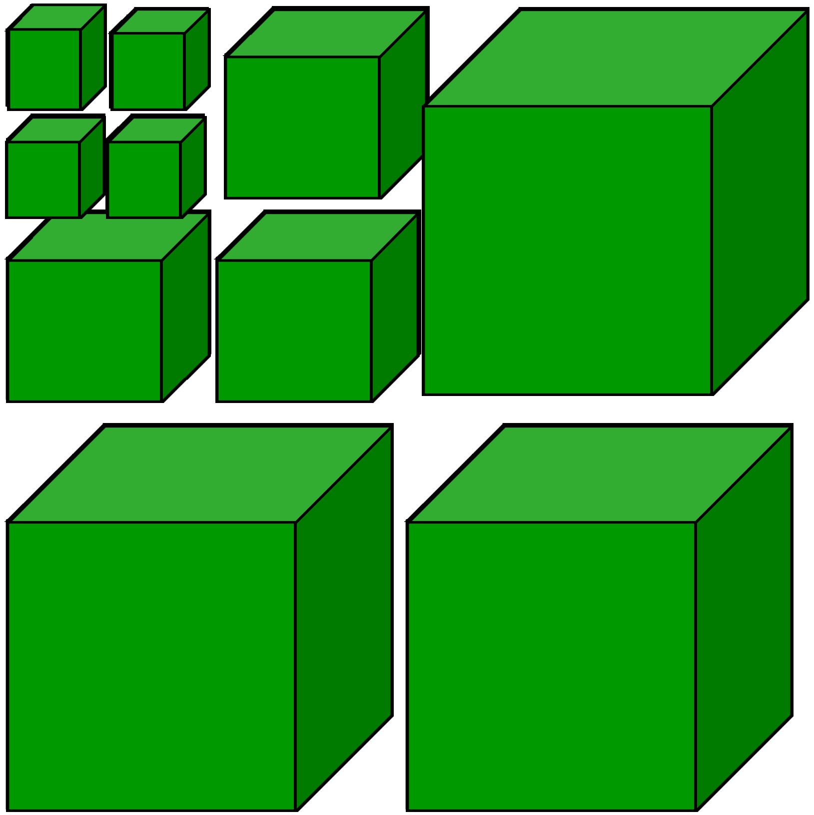
Scalability - Progressive By Accuracy



Scalability - Progressive By Accuracy



Scalability - Progressive By Accuracy



Example: Progressive by resolution

- Image: Woman
- Resolution levels: 5
- Decoded sizes: 1/16
  1/8
  1/4
  1/2
  1