Image compression

- JPEG
- JPEG v.s. JPEG2000
- JPEG 2000
- Evaluating Compressed Images

JPEG v.s. JPEG2000
JPEG2000 features (advantage):
- Very high compression ratios
- Lossy and lossless compression
- Computer-generate images
- Composite images
- Error resilience
- Scalable and flexible encoding/decoding

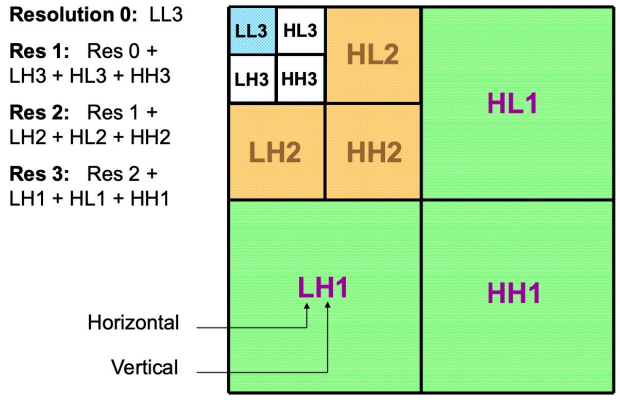
JPEG compression paradigm: a single compressed file can be decomposed to different sizes or qualities using different parts of compressed file — scalable/flexible

JPEG 2000 details
1. 2D wavelet decomposition
2. Tier
3. Layer
4. Region of Interest (ROI)

JPEG overview
Pre-processing —> DWT —> Uniform quantizer —> Tier-1 coding —> rate control —> Tier-2 coding

Preprocessing
Tiling —> Level Offset —> ICT (Irreversible Color Transform)
- Tiling: partition into rectangular
- Level offset: data is centered around 0
- ICT: irreversible color transform (RGB —> YUV) (round of errors)

2D wavelet decomposition

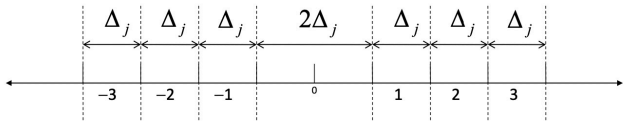


Quantization in JPEG2000 — uniform quantization with dead-zone

- Quantization rule

$$q_j(m,n) = \text{sign}(y_j(m,n)) \left\lfloor \frac{|W_j(m,n)|}{\Delta_j} \right\rfloor$$

y: input to the quantizer
Δ_j: scalar quantizer step size
q: resulting quantizer index
sign(y): sign of y,
$W_j(m,n)$: a DWT coefficient in subband j

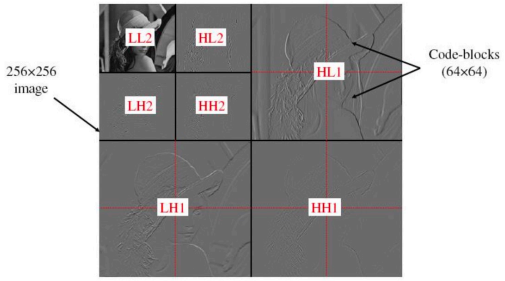


For example: encoder input value = -21.82, quantizer step size = 10

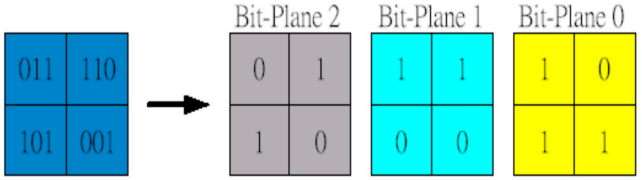
$$-\text{round}\left(\frac{21.82}{10}\right) = -2$$

Entropy Coding in JPEG2000
Tier-1: bit-plane conversion —> fractional bit-plane coding —> arithmetic coding

Code-block: each sub-band from each tile component is partitioned into code blocks
Bit-plane: each code block will be entropy-encoded bit-plane by bit-plane



Code-block

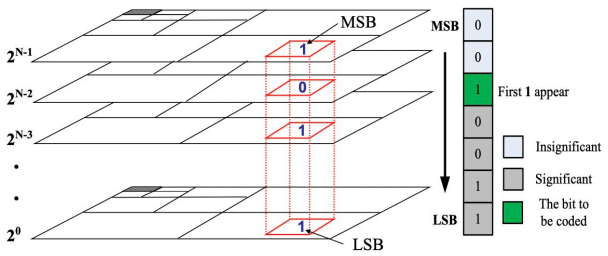


Bit-plane

Bit-plane: a set of bits corresponding to a given bit position in each of the binary numbers representing the signal

- First bit plane — rough but critical approximation
- Higher bit plane — less contribution to the final stage

EBCOT — embedded quantization by bit-plane coding

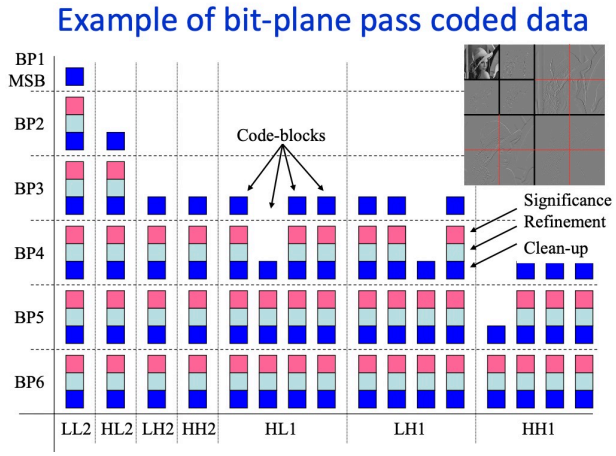


Fractional bitplane coding
To compress each bit plane: three sub bit plane passes
- Significance propagation pass
- Magnitude refinement pass
- Clean up pass

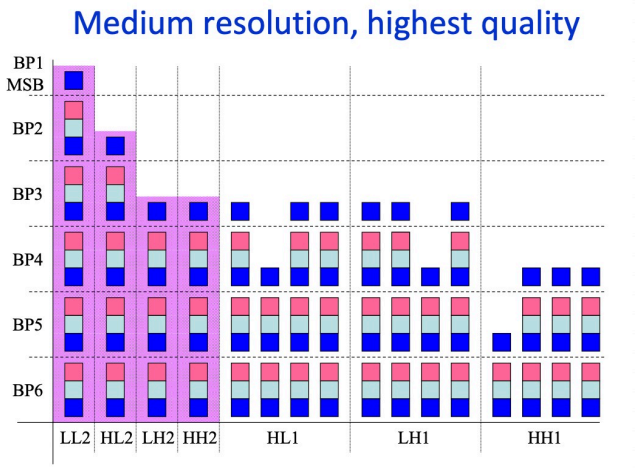
Tier 1 & Tier 2

Tier 1: generate collection of bit-stream: one independent bit-stream for each code-block, each bit-stream is embedded

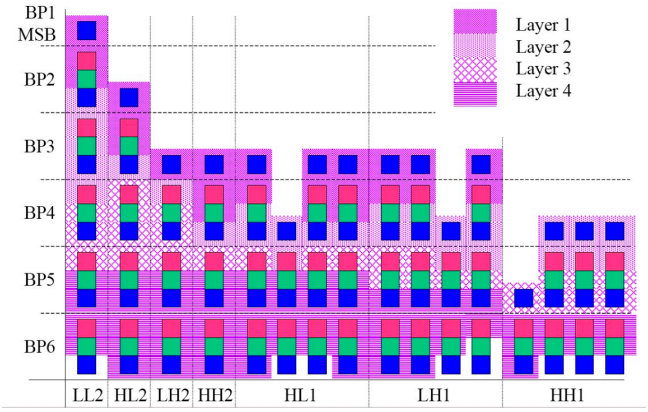
Tier 2:
1. multiplexes the bit-streams
2. signals the ordering of the resulting coded bit-plane
3. coded data can be rather easily parsed
4. enables SNR, resolution, spatial, ROI ... scalability

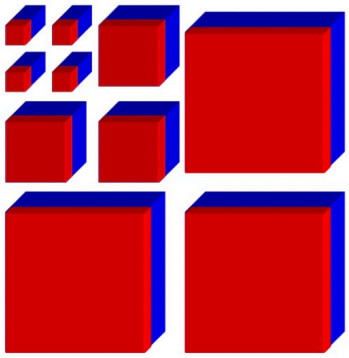


Resolution progressive coding
Lowest resolution, medium resolution, highest resolution —> highest quality

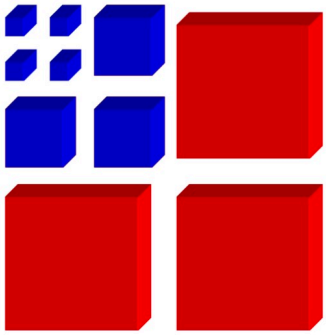


Layer
Layer: each code-block contribute an arbitrary number of bit-plane coding passes to a layer
Each layer increases the image quality





Layer progressive example



Resolution progressive example

Region of Interest (ROI)
ROI: allows a non-uniform distribution of quality. The ROI is coded with higher quality than the background (BG)
A higher compression ratio — same or higher quality inside ROIs

Static ROIs
- Defined at encoding time
- Suitable for storage, fixed transmission, remote sensing

Dynamic ROIs
- Defined interactively by user
- Dynamic generation of layers matching user's request

Evaluating Compressed Images

- Fidelity metrics: simple and have clear physical meanings, but do not reflect perceived visual quality

Mean square error (MSE)

$$MSE = \frac{1}{m\,n} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - K(i,j)]^2$$

Peak signal-to-ratio (PSNR)

$$\begin{aligned} PSNR &= 10 \cdot \log_{10} \left(\frac{MAX_I^2}{MSE} \right) \\ &= 20 \cdot \log_{10} \left(\frac{MAX_I}{\sqrt{MSE}} \right) \\ &= 20 \cdot \log_{10}(MAX_I) - 10 \cdot \log_{10}(MSE) \end{aligned}$$

Perceptual quality metric — incorporate high-level properties of human visual system
Structural similarity: SSIM, MSSIM (multi-scale)

Summary
JPEG 2000:
- High compression ratio
- Lossy and lossless compression
- Computer-generated images
- Composite images
- Error resilience
- Scalable and flexible encoding/decoding

Preprocessing —> Wavelet —> Quantization —> Tier 1 —> Tier 2

Preprocessing: Tier, level offset, ICT

Wavelet: wavelet decomposition — multi-resolution

Quantization

Tier 1: bit-plane conversion, fractional bit-plane coding
Tier 1 generates a collection of bit-streams, one independent bit stream for each code block, each bit-stream is embedded
Bit plane: a set of bits corresponding to a bit position in each binary numbers
EBCOT
Fractional bit-plane coding: three sub bit plane passes (significance propagation, magnitude refinement, clean up)

Tier 2:
- Multiplexes the bit-streams
- Ordering of the resulting coded bit-plane passes
- Coded data can be easily parsed
- Enables SNR, resolution, ... scalability

Resolution progressive coding
Layer progressive coding

Layer: each code block can contribute arbitrary number of bit plane passes to a layer

ROI: region of interest
1. allows non-uniform quality
2. ROI has higher quality than the background (BG)
3. Higher compression ratio with same or higher quality in ROI

Static: 1. Defined at encoding 2. Fixed transmission, storage
Dynamic: 1. Defined interactively 2. Dynamic generation of layers

Evaluating Compressed Images
Fidelity metric: not reflect received visual quality (MSE, PSNR)
MSE越大，噪声越大；PSNR越大，噪声越小
Perceptual quality metric: SSIM, MSSIM

c) This question is about **JPEG 2000**.

[8 marks]

i) Comparing to JPEG, describe at least **four** advantages of JPEG 2000.

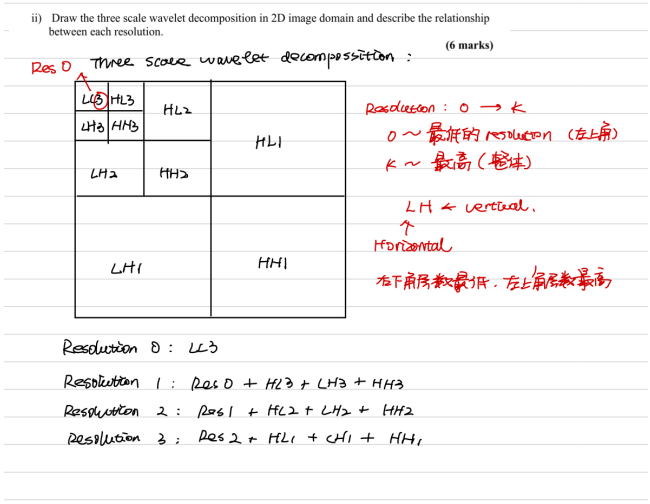
(2 marks)

ii) Draw the three scale wavelet decomposition in 2D image domain and describe the relationship between each resolution.

(6 marks)

(1) 1. JPEG 2000 has a higher compression ratio comparing to JPEG. For the same quality for the same image, JPEG 2000 usually has a higher compression ratio 2. JPEG 2000 can deal with computer generated images where JPEG cannot. 3. JPEG 2000 can handle with composite images where JPEG cannot. 4. JPEG 2000 has a higher error resilience capability than JPEG 5. JPEG 2000 possess scalable and flexible encoding and decoding

(2)



c) This question is about **JPEG 2000**.

[6 marks]

i) Describe the features of Region of Interest (RoI) coding principle

(3 marks)

ii) In Region of Interest coding principle, describe the feature of static ROIs and dynamic ROIs

(3 marks)

(1) RoI allows the non-uniform quality distribution, the region in ROI has a higher quality than background. Higher compression ratio can be achieved with same or higher quality in ROI.

(2) Static ROI is defined at the encoding time, it is mainly used in storage, fixed-transmission and remote sensing. Dynamic ROI is defined interactively by the users/ clients. Dynamic layer progressive are used to meet the users' requirement. Suitable for mobile communication and telemedicine etc.