Network & Media Laboratory

Fundamentals of Multimedia

Authored by Ze-Nian Li Mark S. Drew

Lecturer： Lu Dongming

8、Image Compression Standards

Content

- The JPEG Standard
- The JPEG2000 Standard*
- The JPEG-LS Standard
- Bi-level Image Compression Standards

1. The JPEG Standard

Introduction

- JPEG : Joint Photographic Experts Group
  - Original name：The committee of the International Organization for Standardization (ISO)
  - The first international static image compression standard Published in 1992： ISO 10918-1

- Because of its pleasing properties, JPEG gained great success only several years after published
  - Almost 80 percents of images on web are compressed by the JPEG standards

1.1 Main Steps in JPEG Image Compression

- **Observations**
  - **Useful image contents change relatively slowly across image**
    - **Intensity values rarely vary widely in a small area (8*8)**
  - **Psychophysical experiments**
    - **Humans are much less likely to notice the loss of high-spatial-frequency components than lower-frequency components**
  - **Visual acuity is much greater for gray than for color**

1.1 Main Steps in JPEG Image Compression

（1）Transform RGB to YIQ or YUV and subsample color

（2）Perform DCT on image blocks

（3）Apply Quantization

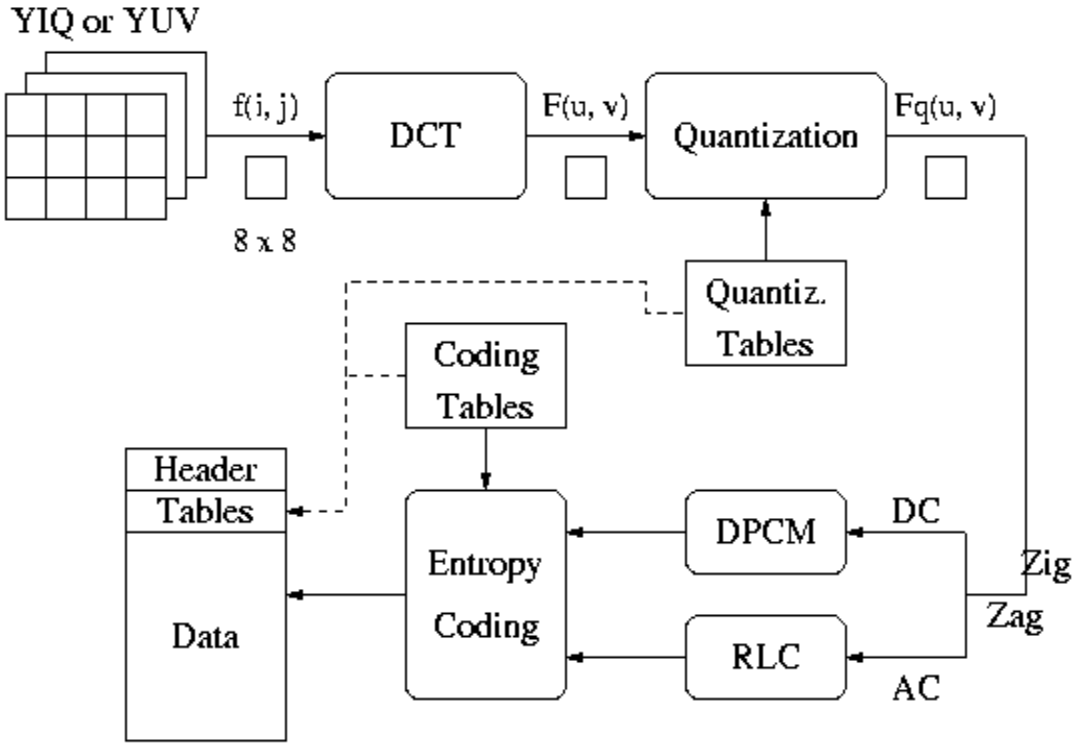
（4）Zigzag Ordering

（5）DPCM on DC coefficients

（6）RLE on AC coefficients

（7）Perform entropy coding

1.1 Main Steps in JPEG Image Compression

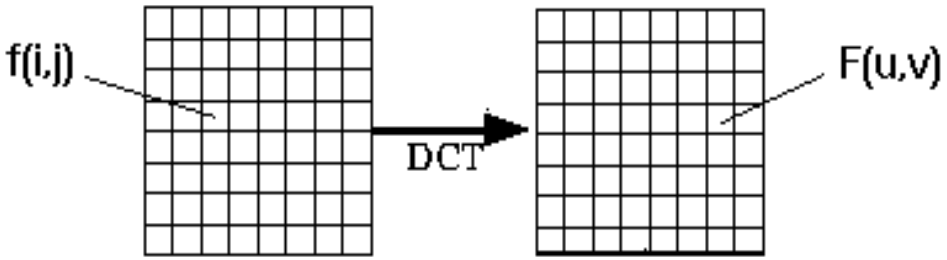


Block diagram for JPEG encoder

1.1 Main steps: DCT

DCT (Discrete Cosine Transformation)

- Each image is divided into 8×8 blocks
- Why the block size is 8×8?
  - Compromise between accuracy and computation
- Removing blocking artifacts is an important concern of researcher



1.1 Main steps: Quantization

$$\hat{F}(u,v) = round(F(u,v)/Q(u,v))$$

Luminance quantization table

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

Chrominance quantization table

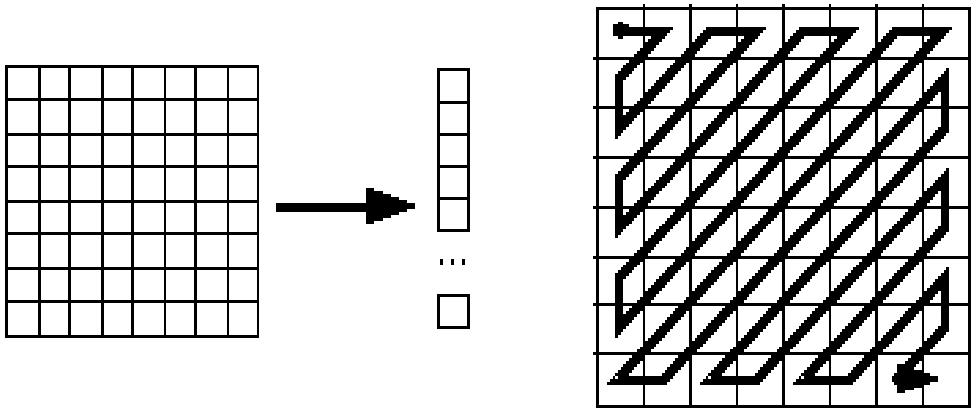
17	18	24	47	99	99	99	99
18	21	26	66	99	99	99	99
24	26	56	99	99	99	99	99
47	66	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99

Suggested Step Sizes for CCIR-601

- Reducing the total number of bits needed
- The main source for information loss
- Introduce more loss for quickly changing image areas

1.1 Main steps: Zigzag Scan

- Turns the 8×8 matrix into a 64 vector
  - Lower frequency components are at the front part of the vector
  - The higher frequency component at the rear part



1.1 Main steps: DPCM on DC Coefficients

- **Coding the difference with the DC of the previous 8×8 block**
  - **DC coefficient is usually large**
  - **It's unlikely change much within a short distance**
  - **DPCM（Differential Pulse Code Modulation）**

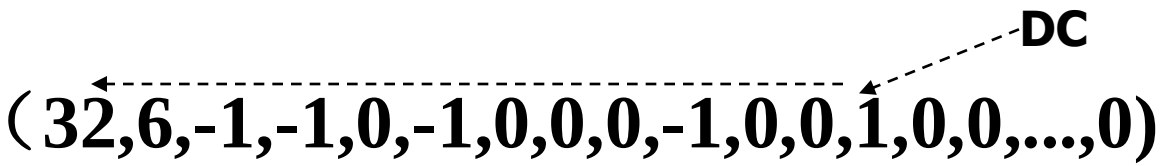
$$d_i = DC_{i+1} - DC_i$$

$$d_0 = DC_0$$

$$150,155,149,152,144 \Rightarrow 150,5,-6,3,-8$$

1.1 Main steps: RLE on AC Coefficients

- The 1 x 64 size vector contains long runs of zeros
- RLE (Run-length Coding):
  - *(skip, value)*
  - *skip: number of zeros, value: the next nonzero value*
  - (0,0): the end of a block



(0,6) (0,-1) (0,-1) (1,-1) (3,-1) (2,1) (0,0)

1.1 Main steps: Entropy Coding (1)

- **DC is represented by a pair of symbols**
  - **(size, amplitude)**

Size	Amplitude
1	-1, 1
2	-3, -2, 2, 3
3	-7..-4, 4..7
4	-15..-8, 8..15
. . . . .	
10	-1023..-512, 512..1023

- **e.g. : (150, 5, -6, 3, -8)** ⟶

(8, 10010110), (3, 101), (3, 001), (2, 11), (4, 0111)

1.1 Main steps: Entropy Coding (2)

- **e.g. : (150, 5, -6, 3, -8)** ⟶

  (8, 10010110), (3, 101), (3, 001), (2, 11), (4, 0111)

  - **Size is Huffman coded**
  - **Amplitude is not Huffman coded**
- **Huffman table can be customized and stored in image header, otherwise, a default Huffman table is used.**
- **AC Coefficient -- two symbols:**
  - **Symbol_1: (RUNLENGTH, *SIZE*)**
  - **Symbol_2: (AMPLITUDE)**
- **Symbol_1 using Huffman coding, Symbol_2 is not**

1.2 JPEG Modes

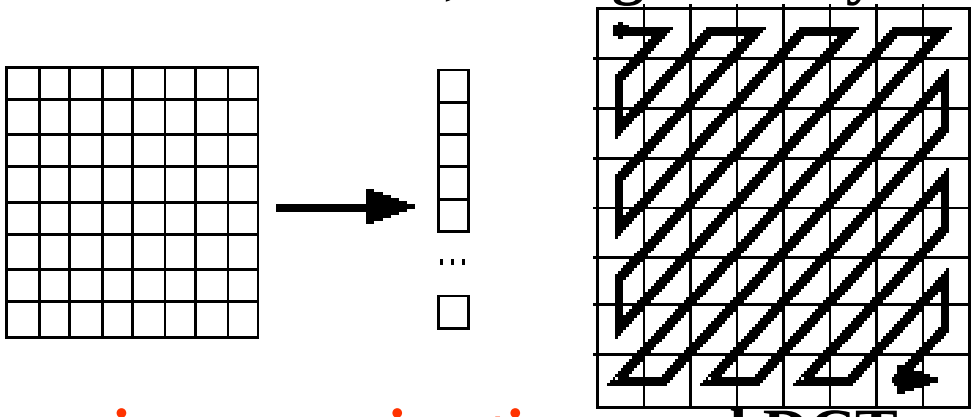
- Sequential Mode
- Progressive Mode
- Hierarchical Mode
- Lossless Mode

1.2 JPEG Mode : Sequential

- The Default JPEG mode
- Each image is encoded in a single left-to-right, top-to-bottom scan
- "Motion JPEG" video coded uses baseline sequential JPEG

1.2 JPEG Mode: Progressive

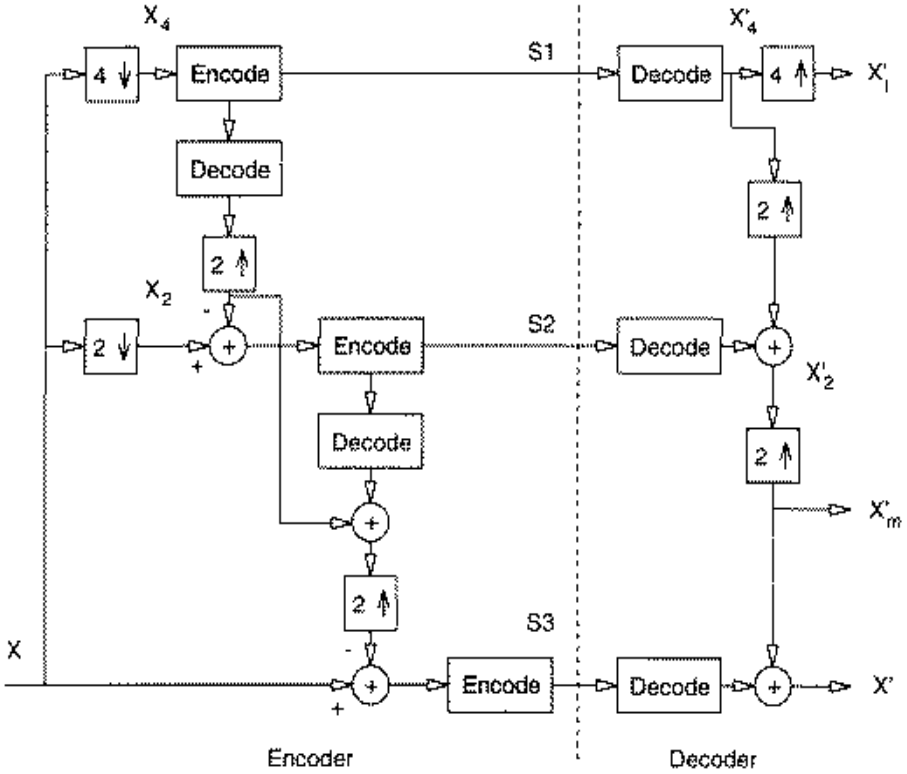
- Delivers low quality image quickly and successively improve.
- Two ways to successively improve image:
  - *Spectral selection*: Send DC component and first few AC coefficients first, then gradually some more ACs.



  - *Successive approximation*: send DCT coefficients MSB (most significant bit) to LSB (least significant bit).

1.2 JPEG Mode: Hierarchical(1)

Encode an image in a hierarchy of several different resolutions



Block diagram for Hierarchical JPEG

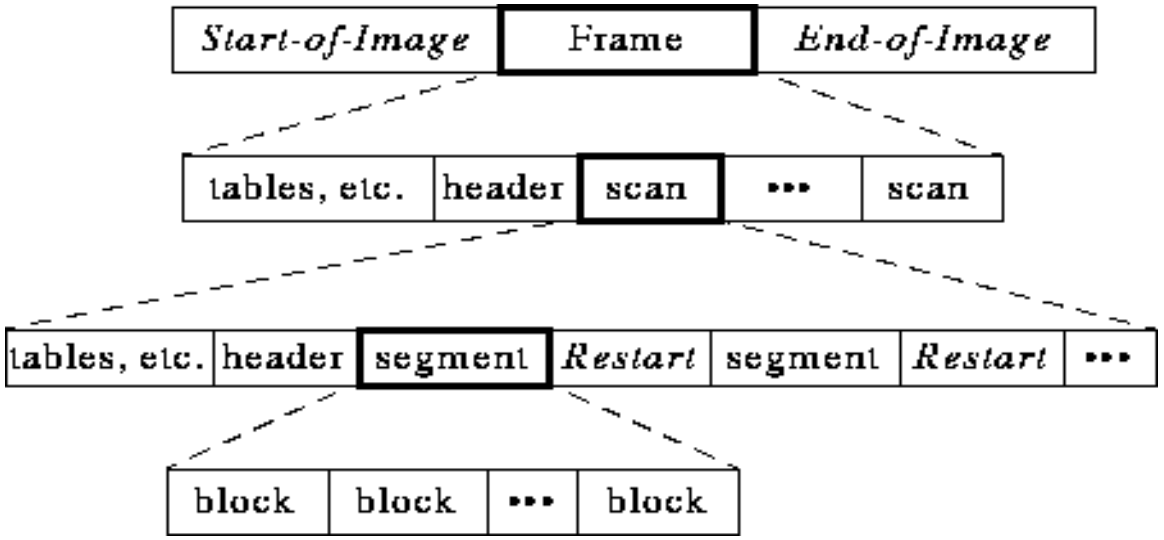
1.2 JPEG Mode: Hierarchical(2)

- **Down-sample by factors of 2 in each dimension**
  - **e.g., reduce 640 x 480 to 320 x 240**
- **Code smaller image using another JPEG mode**
  - **(Progressive, Sequential, or Lossless)**
- **Decode and Up-sample encoded image**
- **Encode difference between the up-sampled and the original: using Progressive, Sequential, or Lossless**

1.2 JPEG Mode: Lossless

- A special case of the JPEG where indeed there is no loss in its image quality
- It does not use DCT-based method! Instead, it uses a *predictive* (differential coding) method
- It's rarely used, since its compression ratio is very low compared to other lossy mode

1.3 A Glance at the JPEG Bitstream



JPEG Bitstream

A "Frame" is a picture, a "scan" is a pass through the pixels (e.g., the red component), a "segment" is a group of blocks, a "block" is an 8 x 8 group of pixels.

1.3 A Glance at the JPEG Bitstream

- **Frame header**
  - **Sample precision (Bits per pixel)**
  - **(width, height) of image**
  - **Number of components**
  - **Unique ID (for each component)**
  - **Horizontal/vertical sampling factors (for each component)**
  - **Quantization table to use (for each component)**
- **Scan header**
  - **Number of components in scan**
  - **Component ID (for each component)**
  - **Huffman table (for each component)**

2. The JPEG2000 Standard(*)

2.1 Why JPEG 2000

- A new-generation image compression standard
  - Provide both lossless compression and lossy compression in a same scheme
  - Excellent rate-distortion at low-bitrate compression
  - ROI (Region of interest) coding
  - Large image
  - Single decompression architecture
  - Transmission in noisy environments
  - Progressive transmission
  - Computer-generated imagery
  - Compound documents

2.2 Main steps of JPEG2000 compression*

- **EBCOT**：**Embedded Block Coding with Optimized Truncation**
  - **The main compression method used in JPEG2000**
    - **Quality and resolution scalability**
    - **Random access, error resilience**
  - **The basic idea: Partition each subband LL, LH, HL, HH produced by the wavelet transform into code blocks**

- **Three steps of EBCOT**
  - **Block coding and bitstream generation**
  - **Post-Compression Rate Distortion (PCRD) optimization**
  - **Layer formation and representation**

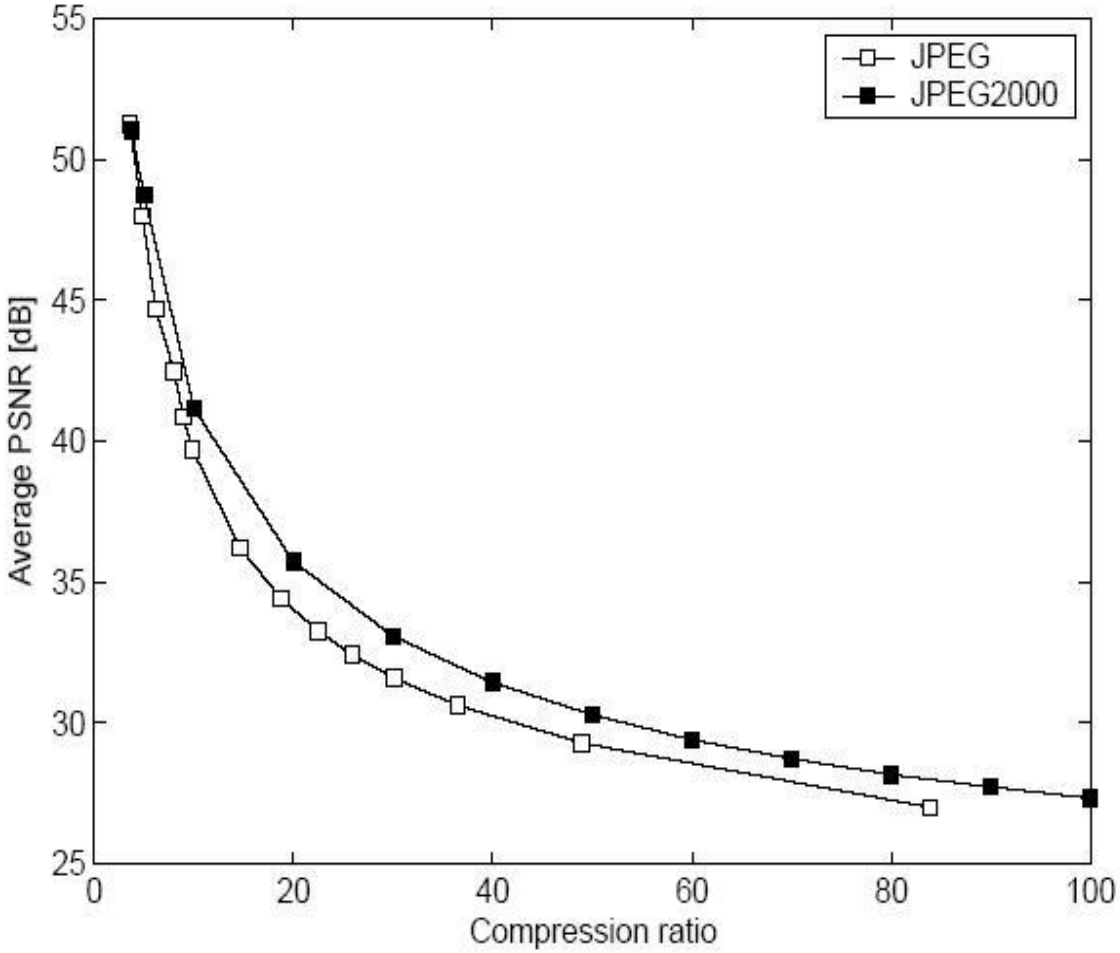
2.3 Region-of-Interest coding

- **MAXSHIFT: (ROI) can be coded with better quality than the rest of the image**

1.0bpp

0.5bpp

2.4 Comparison for JPEG and JPEG2000



3. The JPEG-LS Standard

Introduction to JPEG-LS Standard

- A scheme in competition with the lossless mode in JPEG2000
- The current ISO/ITU standard for lossless or "near lossless" compression standard for continuous-tone image.

- Aimed at better compression of medical images
- The core algorithm is LOCO-I

3.1 The Core Algorithm of JPEG-LS

- LOCO-I (LOw COmplexity LOssless COmpression for Image) broken down into three components
  - Prediction
  - Context determination
  - Residual Coding

3.2 Prediction

c	a	d
b	x	

$$\hat{x}' = \begin{cases} \min(a,b) & c \geq \max(a,b) \\ \max(a,b) & c \leq \min(a,b) \\ a+b-c & otherwise \end{cases}$$

3.3 Context Determination

- Using a three-component context vector Q = (q1, q2, q3) represent the local gradient：
  - q1=d-b;
  - q2=b-c;
  - q3=c-a;
- Q is quantized with decision boundaries -T,…,-1,0,1,…T to reduce the parameters
- In JPEG-LS T=4: number of different context states is：

$$\frac{(2T+1)^3+1}{2}=365$$

3.4 Residual coding

- Error residuals follow a two-side geometric distribution - TSGD
- Coded using adaptively selected codes based on Golomb codes
- Reference：
  - Optimal prefix codes for sources with two-sided geometric distributions
  - （http://netmedia.zju.edu.cn/multimedia2013）

4. Bi-level Image Compression Standards

4. 1 The JBIG Standard

- **JBIG: Joint Bi-level Image Processing Group for binary images**
  - **Offers progressive encoding and decoding capability**
  - **The standard is used primarily to code scanned images of printed or handwritten text**
  - **Also can be used to code grayscale and color images, but this is not the main objective.**

4.2 The JBIG Standard

- Three separate modes of operation
  - Progressive
  - Progressive-Compatible sequential
  - Single-progression sequential
- Encoder can be decomposed into two components
  - Resolution-reduction and differential-layer encoder
  - Lowest-resolution-layer encoder

4.3 The JBIG2 Standard

- The lossy image produced by the JBIG Standard has lower quality than the original.
- JBIG2 offers lossy, lossless, and lossy to lossless image compression, has higher compression ratio and quality.
  - Quality Progressive
  - Content Progressive
- Model-Based coding
  - Text-Region Coding; Halftone-Region Coding
- Preprocessing and Postprocessing

The end!

Thanks !