Research Institute for Future Media Computing
未来媒体技术与研究所

Institute of Computer Vision
计算机视觉研究所

多媒体系统导论

Fundamentals of Multimedia System

授课教师：文嘉俊
邮箱：wenjiajun@szu.edu.cn

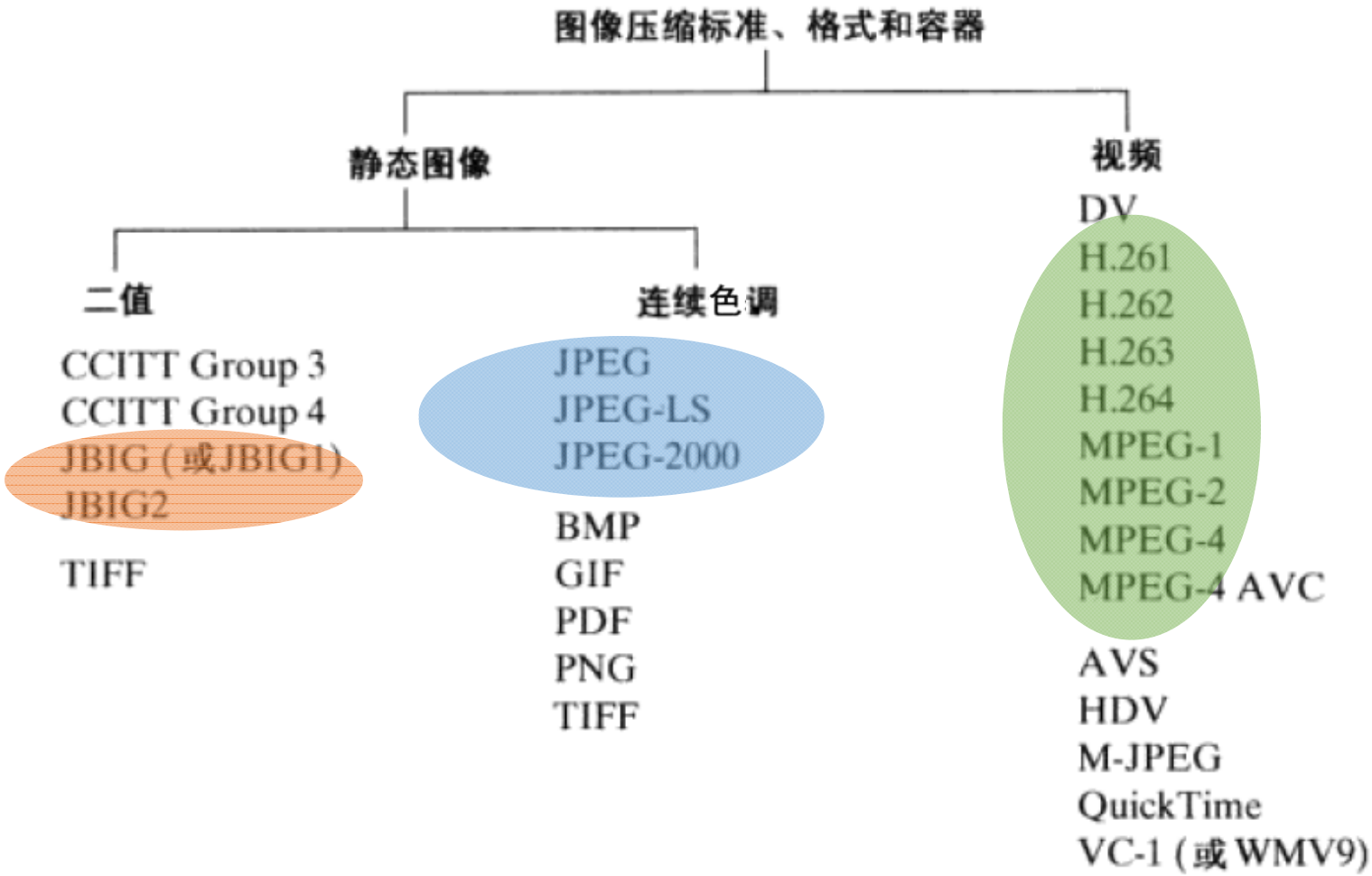
2022年春季课程

Outline of Lecture 11

- JPEG Standard-JPEG标准
  - Main Steps in JPEG Image Compression-压缩主要步骤
  - JPEG Modes-JPEG模式
  - A Glance at the JPEG Bitstream-JPEG位流概述
- JPEG2000 Standard- JPEG2000标准
  - Main Steps of JPEG2000 Image Compression-主要步骤
  - Region-of-Interest Coding-感兴趣区域编码
  - Comparison of JPEG and JPEG2000 Performance-比较
- JPEG-LS Standard- JPEG-LS标准
- Bi-level Image Compression -二值图像压缩标准
- Experiments-实验

JPEG Standard-JPEG标准

- What is JPEG Standard-什么是JPEG标准



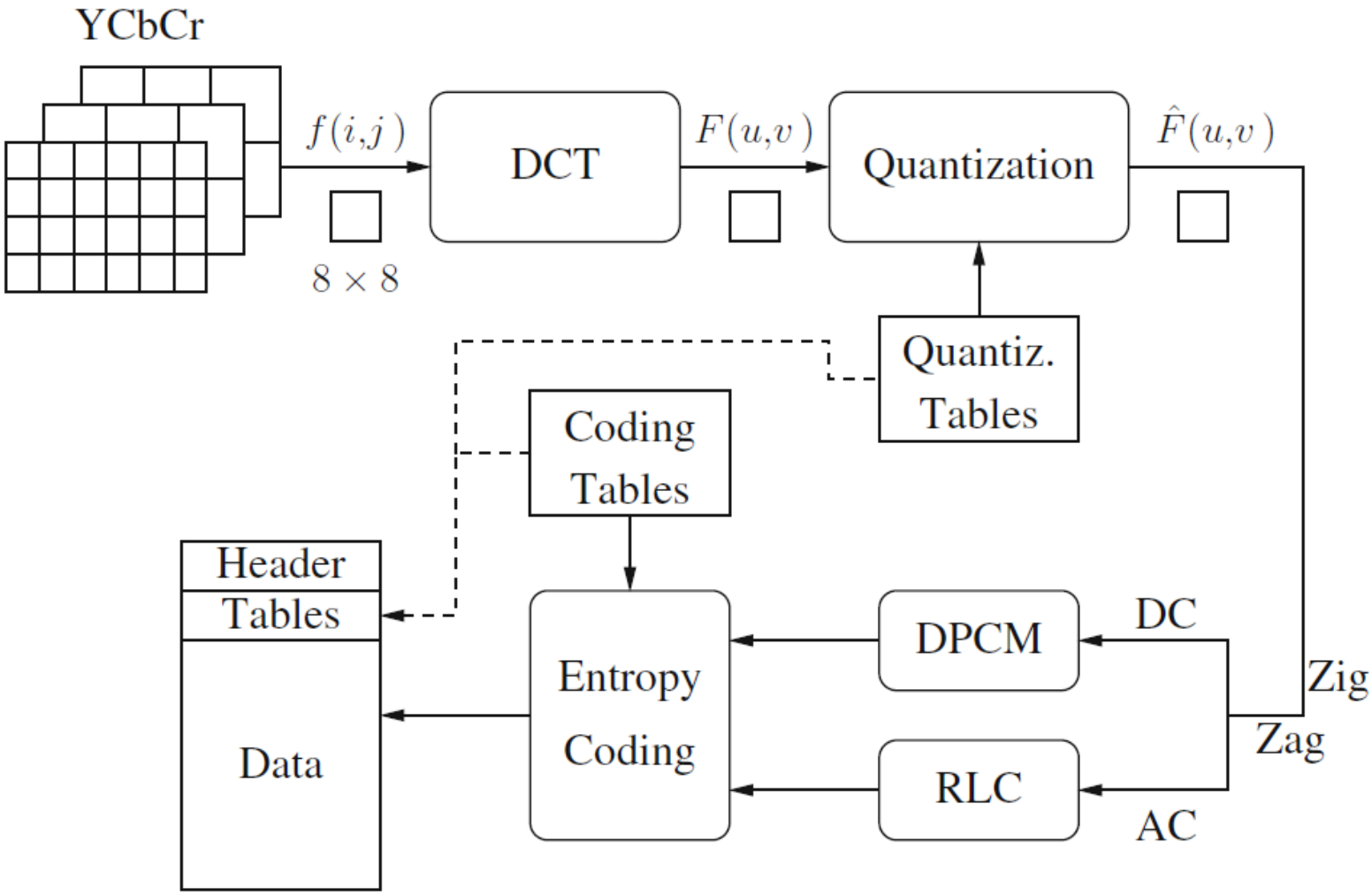
JPEG Standard-JPEG标准

- What is JPEG Standard-什么是JPEG标准
  - JPEG is an image compression standard developed by the *Joint Photographic Experts Group*. It was formally accepted as an international standard in 1992-联合图像专家1992年提出，成为国际标准.
  - JPEG is a **lossy** image compression method. It employs a **transform coding** method using the DCT (Discrete Cosine Transform)-有损，DCT变换编码.
  - The 2D DCT is used as one step in JPEG in order to yield a frequency response which is a function $F(u, v)$ in the spatial frequency domain, indexed by two integers u and v-计算图像$f(i, j)$空间频域的响应函数$F(u, v)$.

JPEG Standard-JPEG标准

- Observations for JPEG Compression-主要特性
  - The effectiveness of the DCT transform coding method in JPEG relies on 3 major observations:
  - **Observation 1**: Useful image contents *change slowly* across the image-图像局部相对变化慢-减少空间冗余.
  - **Observation 2**: Psychophysical experiments suggest that humans are *much less likely to notice the loss of very high spatial frequency* components than the loss of lower frequency components-高频感知远低于低频-减少高频内容.
  - **Observation 3**: Visual acuity is much greater for gray ("black and white") than for color-对灰度视觉敏感远高于彩色-减少颜色信息(色度二次采样4:2:0).

JPEG Standard-JPEG标准



Block diagram for JPEG encoder

JPEG编码器结构图

JPEG Standard-JPEG标准

- Main Steps in JPEG Compression-主要步骤
  - Transform RGB to YCbCr and subsample color (RGB转换成YCbCr并进行色度二次采样)
  - DCT on image blocks-对图像块执行DCT.
  - Quantization-量化.
  - Zig-zag ordering and run-length encoding (Z字形编序和游程编码)
  - Entropy coding-熵编码

JPEG Standard-JPEG标准

- DCT on image blocks-图像块的DCT
  - Each image is divided into *8*8* blocks. The 2D DCT is applied to each block image $f(i, j)$, with output being the *DCT coefficients* $F(u, v)$ for each block -8*8图像块(计算快)，求块的DCT系数$F(u, v)$.
  - Using blocks, however, has the effect of isolating each block from its neighboring context. This is why JPEG images look choppy ("blocky") when a high compression ratio is specified-高压缩率图像不连贯成块状.

JPEG Standard-JPEG标准

- Quantization-量化
  - The quantization step in JPEG is aimed at reducing the total number of bits needed for a compressed image-量化是为了减少压缩图像的总位数:

$$\hat{F}(u,v) = \text{round}\left(\frac{F(u,v)}{Q(u,v)}\right)$$

DCT系数

量化矩阵

  - The quantization step is the main source for loss in JPEG compression-量化是导致信息损失的主要原因.
  - $Q(u,v)$ tend to have larger values towards the lower right corner. This aims to introduce more loss at the higher spatial frequencies-量化矩阵右下角值更大，丢弃更多的高频信息.
  - 可通过量化矩阵乘比例值来改变压缩率.

JPEG Standard-JPEG标准

- Quantization-量化

亮度量化矩阵

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

色度量化矩阵

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

JPEG Standard-JPEG标准

- Quantization-量化

平滑灰度图像块

An 8×8 block from the Y image of 'Lena'

200	202	189	188	189	175	175	175
200	203	198	188	189	182	178	175
203	200	200	195	200	187	185	175
200	200	200	200	197	187	187	187
200	205	200	200	195	188	187	175
200	200	200	200	200	190	187	175
205	200	199	200	191	187	187	175
210	200	200	200	188	185	187	186

$f(i,j)$

515	65	-12	4	1	2	-8	5
-16	3	2	0	0	-11	-2	3
-12	6	11	-1	3	0	1	-2
-8	3	-4	2	-2	-3	-5	-2
0	-2	7	-5	4	0	-1	-4
0	-3	-1	0	4	1	-1	0
3	-2	-3	3	3	-1	-1	3
-2	5	-2	4	-2	2	-3	0

$F(u,v)$

JPEG Standard-JPEG标准

- Quantization-量化

32	6	-1	0	0	0	0	0
-1	0	0	0	0	0	0	0
-1	0	1	0	0	0	0	0
-1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

量化后DCT系数 $\hat{F}(u,v)$

512	66	-10	0	0	0	0	0
-12	0	0	0	0	0	0	0
-14	0	16	0	0	0	0	0
-14	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

去量化后DCT系数 $\tilde{F}(u,v)$

199	196	191	186	182	178	177	176
201	199	196	192	188	183	180	178
203	203	202	200	195	189	183	180
202	203	204	203	198	191	183	179
200	201	202	201	196	189	182	177
200	200	199	197	192	186	181	177
204	202	199	195	190	186	183	181
207	204	200	194	190	187	185	184

重构后图像块 $\tilde{f}(i,j)$

1	6	-2	2	7	-3	-2	-1
-1	4	2	-4	1	-1	-2	-3
0	-3	-2	-5	5	-2	2	-5
-2	-3	-4	-3	-1	-4	4	8
0	4	-2	-1	-1	-1	5	-2
0	0	1	3	8	4	6	-2
1	-2	0	5	1	1	4	-6
3	-4	0	6	-2	-2	2	2

重构误差 $\epsilon(i,j) = f(i,j) - \tilde{f}(i,j)$

JPEG Standard-JPEG标准

- Quantization-量化

纹理灰度图像块

Another 8×8 block from the Y image of 'Lena'

70	70	100	70	87	87	150	187
85	100	96	79	87	154	87	113
100	85	116	79	70	87	86	196
136	69	87	200	79	71	117	96
161	70	87	200	103	71	96	113
161	123	147	133	113	113	85	161
146	147	175	100	103	103	163	187
156	146	189	70	113	161	163	197

$f(i,j)$

-80	-40	89	-73	44	32	53	-3
-135	-59	-26	6	14	-3	-13	-28
47	-76	66	-3	-108	-78	33	59
-2	10	-18	0	33	11	-21	1
-1	-9	-22	8	32	65	-36	-1
5	-20	28	-46	3	24	-30	24
6	-20	37	-28	12	-35	33	17
-5	-23	33	-30	17	-5	-4	20

$F(u,v)$

JPEG Standard-JPEG标准

- Quantization-量化

图像变化剧烈，
损失较大

-5	-4	9	-5	2	1	1	0
-11	-5	-2	0	1	0	0	-1
3	-6	4	0	-3	-1	0	1
0	1	-1	0	1	0	0	0
0	0	-1	0	0	1	0	0
0	-1	1	-1	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

量化后DCT系数 $\hat{F}(u,v)$

-80	-44	90	-80	48	40	51	0
-132	-60	-28	0	26	0	0	-55
42	-78	64	0	-120	-57	0	56
0	17	-22	0	51	0	0	0
0	0	-37	0	0	109	0	0
0	-35	55	-64	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

去量化后DCT系数 $\tilde{F}(u,v)$

70	60	106	94	62	103	146	176
85	101	85	75	102	127	93	144
98	99	92	102	74	98	89	167
132	53	111	180	55	70	106	145
173	57	114	207	111	89	84	90
164	123	131	135	133	92	85	162
141	159	169	73	106	101	149	224
150	141	195	79	107	147	210	153

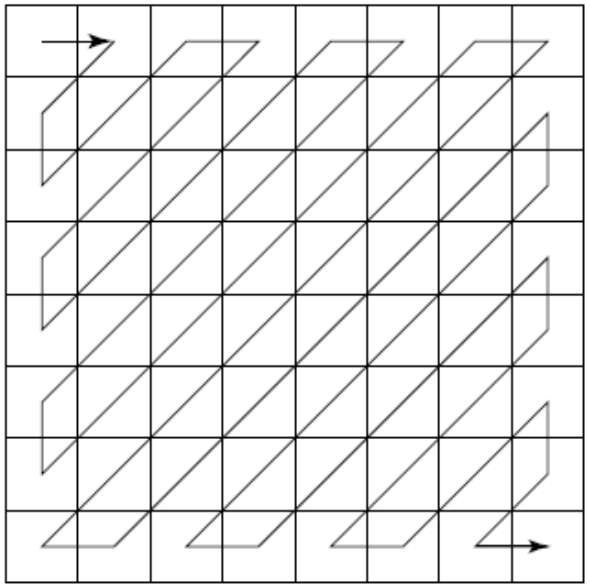
重构后图像块 $\tilde{f}(i,j)$

0	10	-6	-24	25	-16	4	11
0	-1	11	4	-15	27	-6	-31
2	-14	24	-23	-4	-11	-3	29
4	16	-24	20	24	1	11	-49
-12	13	-27	-7	-8	-18	12	23
-3	0	16	-2	-20	21	0	-1
5	-12	6	27	-3	2	14	-37
6	5	-6	-9	6	14	-47	44

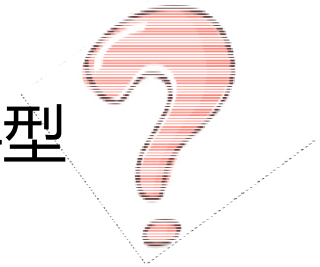
重构误差 $\epsilon(i,j) = f(i,j) - \tilde{f}(i,j)$

JPEG Standard-JPEG标准

- RLC on AC coefficients-AC系数游程编码
  - RLC aims to turn the $\hat{F}(u,v)$ values into sets {*#-zeros-to-skip , next non-zero value*}-量化后DCT系数采用游程编码.
  - To make it most likely to hit a long run of zeros: a zig-zag scan is used to turn the 8*8 matrix $\hat{F}(u,v)$ into a **64**-vector-Z字型扫描更有效，转换为**64位**的向量.



为什么采用Z字型



右下角高频信息

JPEG Standard-JPEG标准

- RLC on AC coefficients-AC系数游程编码

$$\begin{matrix} 32 & 6 & -1 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{matrix}$$

$$\hat{F}(u,v)$$

$$(32, 6, -1, -1, 0, -1, 0, 0, 0, -1, 0, 0, 1, 0, 0, \ldots, 0)$$

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

(RUNLENGTH, VALUE) (跳过0的数目，下一个非零值)

块结尾，减少位数

JPEG Standard-JPEG标准

- DPCM on DC coefficients-DC系数DPCM编码
  - The DC coefficients are coded separately from the AC ones. *Differential Pulse Code Modulation* (DPCM) is the coding method-DC系数单独编码，采用DPCM方法.
  - For example-DC coefficients for the first 5 image blocks are {150, 155, 149, 152, 144}, assuming $\widehat{DC}_i = DC_{i-1}$, and $DC_0 = DC_1$.
  - DPCM output: ? 150, 5, -6, 3, -8,

$$\hat{f}_n = \text{function\_of}\ (\tilde{f}_{n-1}, \tilde{f}_{n-2}, \tilde{f}_{n-3}, \ldots)$$
$$e_n = f_n - \hat{f}_n$$
$$\tilde{e}_n = Q[e_n]$$
$$\text{transmit codeword}(\tilde{e}_n)$$
$$\text{reconstruct: } \tilde{f}_n = \hat{f}_n + \tilde{e}_n$$

JPEG Standard-JPEG标准

- Entropy Coding-熵编码
  - The DC and AC coefficients finally undergo an *entropy coding* step to gain a *possible further compression*-熵编码进一步压缩.
  - **DC coefficients**: each DPCM coded DC coefficient is represented by **(SIZE, AMPLITUDE)**.

Size:表示DC系数需多少位

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

Amplitude:
实际二进制

1）找到值相应的Size
2）二进制表示值，负数用反码，10表示2，01表示-2

JPEG Standard-JPEG标准

- Entropy Coding-熵编码
  - Example-(150, 5, -6, 3, -8)
  - 150->**Size=8**, $(150)_{10}$=**10010110**
  - 5->**Size=3**, $(5)_{10}$=**101**
  - -6->**Size=3**, $(6)_{10}$=110, **$(-6)_{10}$=001**
  - 3->**Size=2**, $(3)_{10}$=**11**
  - -8->**Size=4**, $(8)_{10}$=1000, **$(-8)_{10}$=0111**
  - (8, 10010110), (3, 101), (3, 001), (2, 11), (4, 0111)
  - SIZE is Huffman coded since smaller SIZEs occur much more often. AMPLITUDE is not Huffman coded, its value can
  - change widely so Huffman coding has no appreciable benefit-Amplitude范围过大，不适合进行Huffman编码 JPEG对Size进行编码，编码保留在图像的头部

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

JPEG Standard-JPEG标准

- Entropy Coding-熵编码JPEG Modes-JPEG模式
  - AC coefficients are run-length coded and are represented by pairs of numbers **(RUNLENGTH, VALUE)**. However, in an actual JPEG implementation, VALUE is further represented by SIZE and AMPLITUDE, as for the DCs-AC系数采用游程编码，其中值VALUE用(SIZE, AMPLITUDE)表示.
  - To save bits, RUNLENGTH and SIZE are allocated only *4 bits each* and squeezed into **a single byte**—call this Symbol 1. Symbol 2 is the AMPLITUDE value-游程值和Size值分别用4位，合计1字节，称Symbol 1，AMPLITUDE称Symbol 2.
  - Symbol 1: (RUNLENGTH, SIZE)，赫夫曼编码
  - Symbol 2: (AMPLITUDE)

4位表示0-15，超过15，使用特殊扩展编码(15, 0)

JPEG Standard-JPEG标准

- JPEG Modes-JPEG模式
  - **Sequential Mode**-the default JPEG mode, implicitly assumed in the discussions so far. Each gray level image or color image component is encoded in a single left-to-right, top-to-bottom scan-顺序模式(默认)，从左至右，从上至下，单通道处理.
  - **Progressive Mode-**渐进模式（先传低质图，再传高质量图）.
  - **Hierarchical Mode-**分层模式（针对不同分辨率层次）.
  - **Lossless Mode-**无损模式，相应方法JPEG-LS.

JPEG Standard-JPEG标准

- Progressive Mode-渐进模式
  - Progressive JPEG delivers low quality versions of the image quickly, followed by higher quality passes-先低质量后高质量，多次扫描，Web浏览器.
  - **Spectral selection (光谱选择):** Takes advantage of the "spectral " (spatial frequency spectrum) characteristics of the DCT coefficients: higher AC components provide detail information-更高AC分量提供细节信息-逐次增加AC.

a) *Scan 1*: Encode DC and first few AC components, e.g., AC1, AC2.

b) *Scan 2*: Encode a few more AC components, e.g., AC3, AC4, AC5.

c) *Scan k*: Encode the last few ACs, e.g., AC61, AC62, AC63.

JPEG Standard-JPEG标准

- Progressive Mode-渐进模式
  - **Successive approximation (逐次逼近):** All DCT coefficients are encoded simultaneously but with their *most significant bits* (MSBs) first-更高所有系数同时编码，但先最高有效位.

  a) *Scan 1*: Encode the first few MSBs, e.g., Bits 7, 6, 5, 4.

  b) *Scan 2*: Encode a few more less significant bits, e.g., Bit 3.

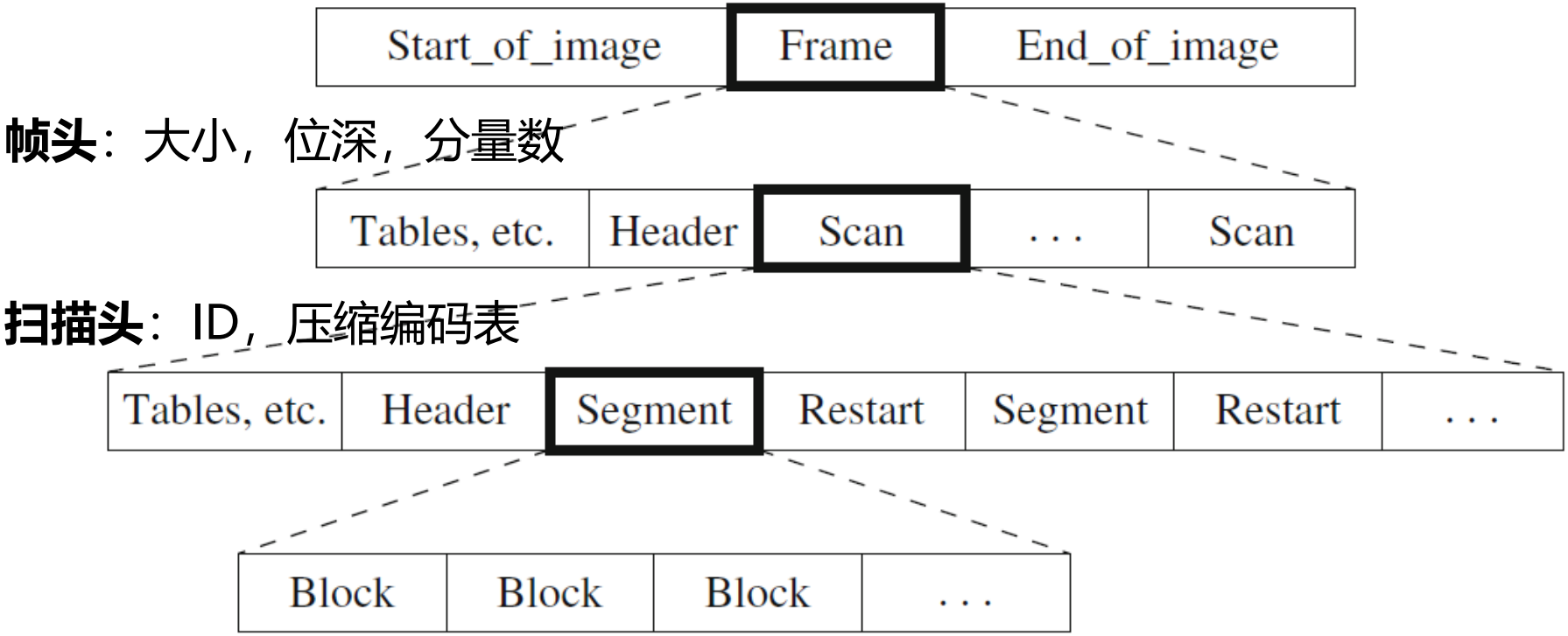
  c) *Scan m*: Encode the least significant bit (LSB), Bit 0.

JPEG Standard-JPEG标准

- Hierarchical Mode-分层模式
  - The encoded image at the lowest resolution is basically a compressed low-pass filtered image, whereas the images at successively higher resolutions provide additional details (differences from the lower resolution images)-低分辨率提供基本信息，高分辨率提供细节信息.
  - Similar to Progressive JPEG, the Hierarchical JPEG images can be transmitted in *multiple passes* progressively improving quality-分层模式通过多次扫描传送改善图像质量.

JPEG Standard-JPEG标准

- A Glance at the JPEG Bitstream- JPEG位流概述
  - **Frame:** 帧，一幅图片
  - **Scan:** 扫描，单通道全部像素
  - **Segment:** 段，一组块；**Block:** 块，8*8像素组成



JPEG位流描述图

Outline of Lecture 11

- JPEG Standard-JPEG标准
  - Main Steps in JPEG Image Compression-压缩主要步骤
  - JPEG Modes-JPEG模式
  - A Glance at the JPEG Bitstream-JPEG位流概述
- JPEG2000 Standard- JPEG2000标准
  - Main Steps of JPEG2000 Image Compression-主要步骤
  - Region-of-Interest Coding-感兴趣区域编码
  - Comparison of JPEG and JPEG2000 Performance-比较
- JPEG-LS- JPEG-LS标准
- Bi-level Image Compression -二值图像压缩标准
- Experiments-实验

JPEG2000 Standard- JPEG2000标准

- Design Goals-目标
  - To provide a better rate-distortion tradeoff and improved subjective image quality-更好权衡压缩率-失真，改善图像质量.
  - To provide additional functionalities lacking in the current JPEG standard-JPEG缺乏的功能.
  - Low Bit-rate Compression-低位率压缩(0.25bpp)
  - Lossless and Lossy Compression-兼顾有损和无损
  - Large Images-大图像(64K*64K)
  - Region of Interest Coding-感兴趣区域编码
  - Multichannel-多通道(256)
  - ……

JPEG2000 Standard- JPEG2000标准

- Properties of JPEG2000 Image Compression
  - Uses *Embedded Block Coding with Optimized Truncation* (EBCOT) algorithm which partitions each subband LL, LH, HL, HH produced by the wavelet transform into small blocks called “code blocks”-最优截断嵌入式块编码-小波变换生成子带，子带分成小块，独立编码，称为码块.
  - The EBCOT algorithm consists of three steps:

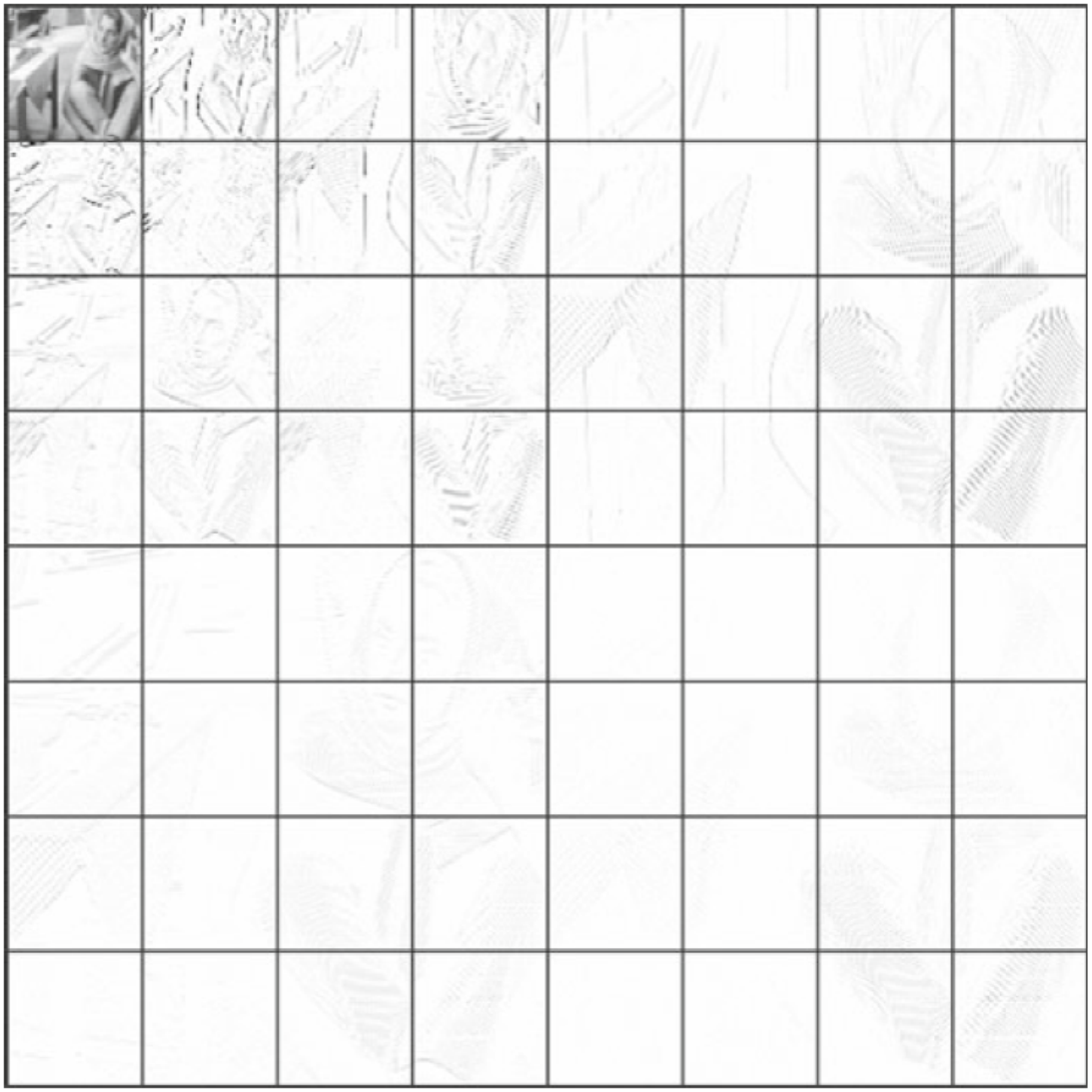
a) Block coding and bitstream generation-块编码和位流生成.

b) Post compression rate distortion optimization-压缩后比例失真优化.

c) Layer formation and representation-层形式化和表示.

JPEG2000 Standard- JPEG2000标准

- Properties of JPEG2000 Image Compression



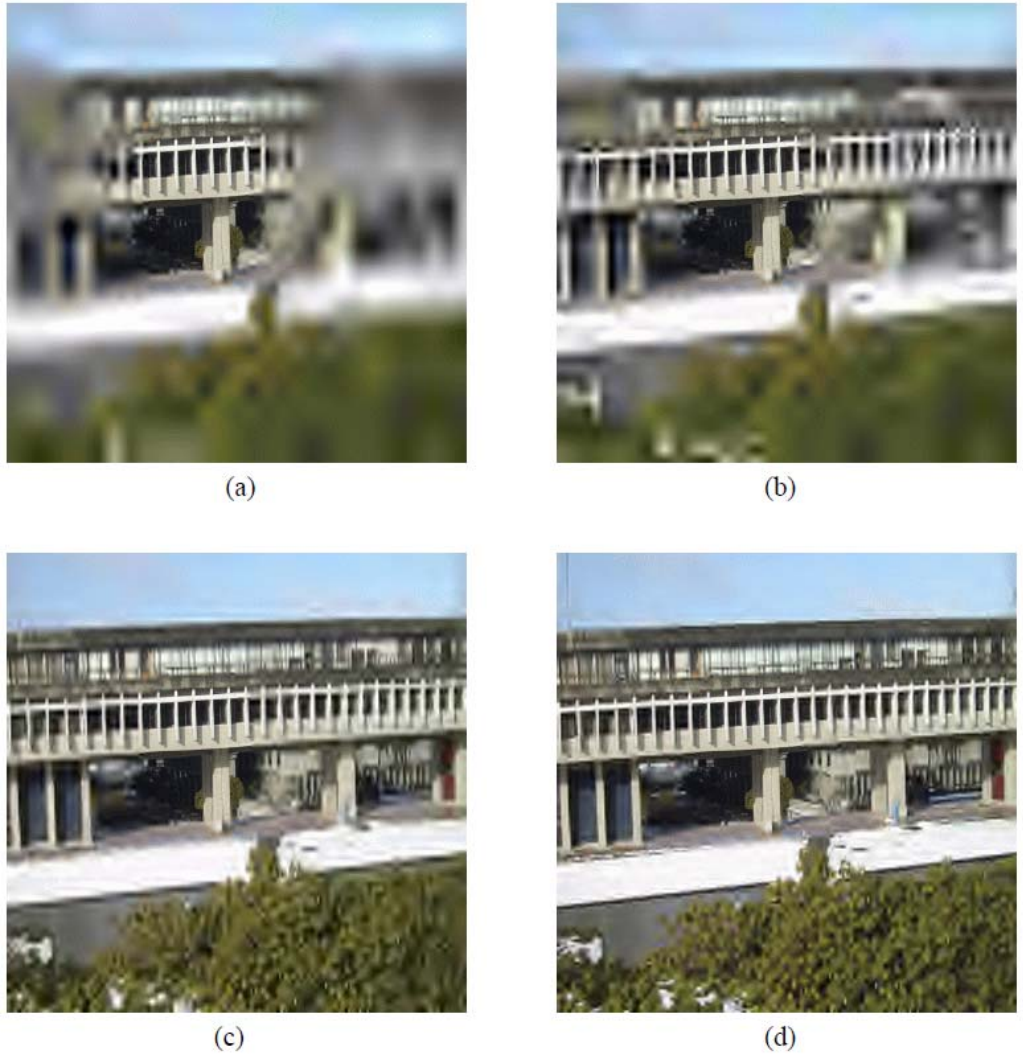
Code block structure of EBCOT

JPEG2000 Standard- JPEG2000标准

- Region-of-Interest Coding-感兴趣区域编码
  - **Goal:** Particular regions of the image may contain important information, thus should be coded with better quality than others-特定区域包含重要信息，需更高质量的编码.
  - Usually implemented using the MAXSHIFT method which scales up the coefficients within the ROI so that they are placed into higher bit-planes-增大ROI区域中的系数，使其位于更高的位平面.
  - During the embedded coding process, the resulting bits are placed in front of the non-ROI part of the image. Therefore, given a reduced bit-rate, the ROI will be decoded and refined before the rest of the image-码率低时，优先解码和细化.

JPEG2000 Standard- JPEG2000标准

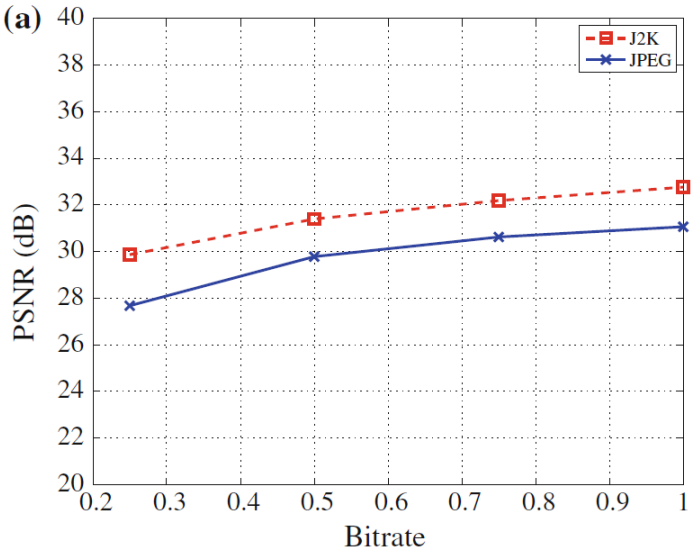
- Region-of-Interest Coding-感兴趣区域编码

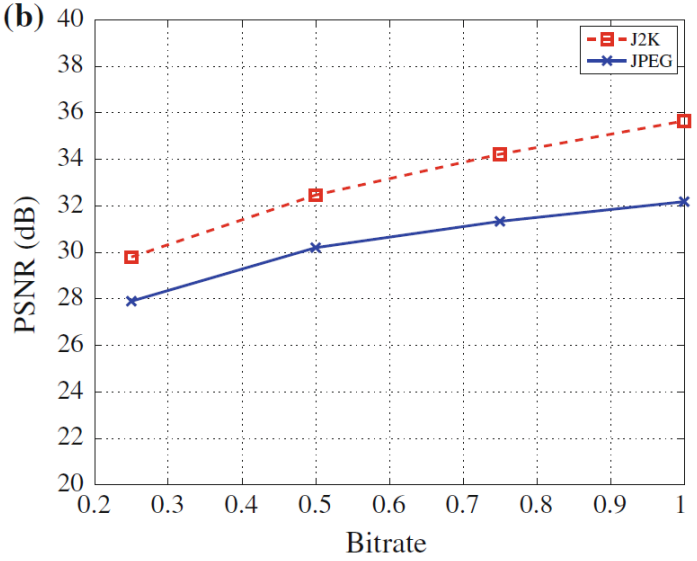


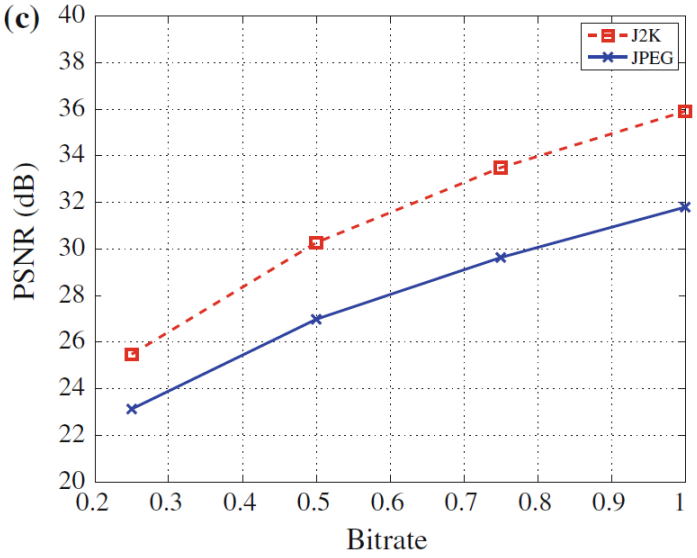
Region of interest (ROI) coding of an image using a circularly shaped ROI. (a) 0.4 bpp, (b) 0.5 bpp, (c) 0.6bpp, and (d) 0.7 bpp.

JPEG2000 Standard- JPEG2000标准

- Comparison of JPEG and JPEG2000 Performance







Performance comparison for JPEG and JPEG2000 on different image types:
(a) Natural images;
(b) Computer-generated images;
(c) Medical images

JPEG2000 Standard- JPEG2000标准

- Comparison of JPEG and JPEG2000 Performance

Performance comparison for JPEG(**Left**) and JPEG2000(**Right**)

Outline of Lecture 11

- JPEG Standard-JPEG标准
  - Main Steps in JPEG Image Compression-压缩主要步骤
  - JPEG Modes-JPEG模式
  - A Glance at the JPEG Bitstream-JPEG位流概述
- JPEG2000 Standard- JPEG2000标准
  - Main Steps of JPEG2000 Image Compression-主要步骤
  - Region-of-Interest Coding-感兴趣区域编码
  - Comparison of JPEG and JPEG2000 Performance-比较
- JPEG-LS- JPEG-LS标准
- Bi-level Image Compression -二值图像压缩标准
- Experiments-实验

JPEG-LS- JPEG-LS标准

- Lossless JPEG-无损压缩JPEG
  - JPEG-LS is in the current ISO/ITU standard for lossless or “near lossless” compression of continuous tone images-医学图像或成本较高的图像，无损或近似无损压缩的标准.
  - Uses the LOCO-I (LOw COmplexity LOssless Compression for Images) algorithm proposed by Hewlett-Packard-低复杂度无损图像压缩算法.
  - Motivated by the observation that complexity reduction is often more important than small increases in compression offered by more complex algorithms-效率为王.
  - **Main Advantage**: Low complexity!

JPEG-LS- JPEG-LS标准

- Lossless JPEG-无损压缩JPEG
  - The LOCO-I algorithm makes uses of *context modelling*-上下文建模.
  - The idea of context modelling is to take advantage of the structure within the input source - the conditional probabilities-利用图像的结构信息.
  - LOCO-I can be broken down into three components:

a) Prediction-预测

b) Context determination-确定上下文

c) Residual coding-残差编码(上下文)

c	a	d
b	x	

JPEG-LS Context Model

Outline of Lecture 11

- JPEG Standard-JPEG标准
  - Main Steps in JPEG Image Compression-压缩主要步骤
  - JPEG Modes-JPEG模式
  - A Glance at the JPEG Bitstream-JPEG位流概述
- JPEG2000 Standard- JPEG2000标准
  - Main Steps of JPEG2000 Image Compression-主要步骤
  - Region-of-Interest Coding-感兴趣区域编码
  - Comparison of JPEG and JPEG2000 Performance-比较
- JPEG-LS- JPEG-LS标准
- Bi-level Image Compression -二值图像压缩标准
- Experiments-实验

Bi-level Image Compression -二值图像

- JBIG and JBIG-2
  - **Main Goal:** Enables the handing of documents in electronic form-文档电子化(传真、印刷文档扫描、手写字).
  - JBIG is the coding standard recommended by the *Joint Bi-level Image Processing Group* for binary images.
  - JBIG is a lossless compression standard. It also offers progressive encoding/decoding capability-无损标准，提供渐近编解码模式.
  - The JBIG encoder can be decomposed into two components:

a) Resolution-reduction and differential-layer encoder-分辨率缩减与差分层编码器

b) Lowest resolution layer encoder-最低分辨率层编码器.

Bi-level Image Compression -二值图像

- JBIG and JBIG-2
  - JBIG2 standard is explicitly designed for lossy, lossless, and lossy to lossless image compression-多种模式.
  - **Main Goal:** providing superior lossless compression performance over existing standards but also at incorporating lossy compression at a much higher compression ratio, with as little visible degradation as possible-提升无损压缩性能，融合有损压缩标准，提高压缩率，避免画质退化.
  - JBIG2 offers content progressive coding and superior compression performance through *model-based coding*-基于模型的编码-与基于上下文的编码类似.

Outline of Lecture 11

- JPEG Standard-JPEG标准
  - Main Steps in JPEG Image Compression-压缩主要步骤
  - JPEG Modes-JPEG模式
  - A Glance at the JPEG Bitstream-JPEG位流概述
- JPEG2000 Standard- JPEG2000标准
  - Main Steps of JPEG2000 Image Compression-主要步骤
  - Region-of-Interest Coding-感兴趣区域编码
  - Comparison of JPEG and JPEG2000 Performance-比较
- JPEG-LS- JPEG-LS标准
- Bi-level Image Compression -二值图像压缩标准
- Experiments-实验

Experiments & Class Assignments

- Experiments
  - Arithmetic Coding--*ch09_jpeg_demo.m*

- Class Assignments

1、给定6个图像块的DC系数为130，135，141，180，182，179，求其赫夫曼编码（注：$\widehat{DC}_i = DC_{i-1}$,）。

2、什么是感兴趣编码，其实现方法的基本思想是什么？