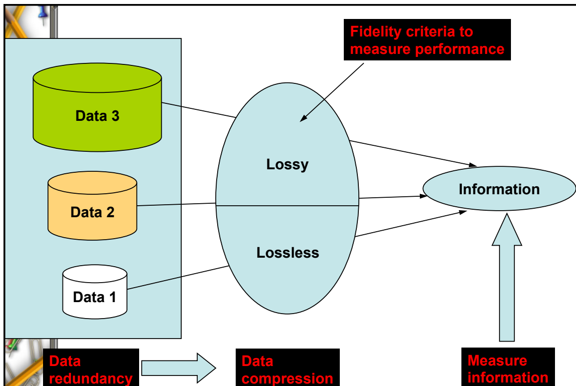
ECE472/572 - Lecture 12

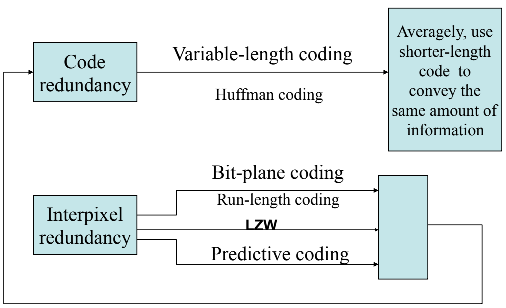
Image Compression – Lossy Compression Techniques
11/10/11



Compression Approaches

- Error-free compression or lossless compression
  - Variable-length coding
  - LZW
  - Bit-plane coding
  - Lossless predictive coding
- Lossy compression
  - Lossy predictive coding
  - Transform coding

Lossless Compression Approaches



Lossy Compression

- Spatial domain methods
  - Lossy predictive coding
    - Delta modulation (DM)
- Transform coding
  - Operate on the transformed image

Lossy Predictive Coding

- Prediction + quantization

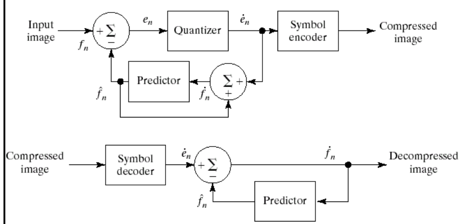
Predictor → $\hat{f}_n = \alpha \dot{f}_{n-1}$

Error → $\hat{e}_n = f_n - \hat{f}_n$

Delta Modulation

Error quantization → $\dot{e}_n = \begin{cases} \delta & \text{if } \hat{e}_n > 0 \\ -\delta & \text{otherwise} \end{cases}$

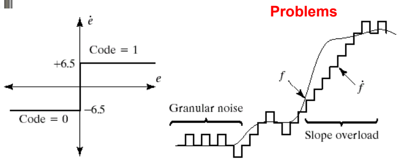
Prediction → $\dot{f}_n = \dot{e}_n + \hat{f}_n$



a
b

FIGURE 8.21 A lossy predictive coding model: (a) encoder and (b) decoder.

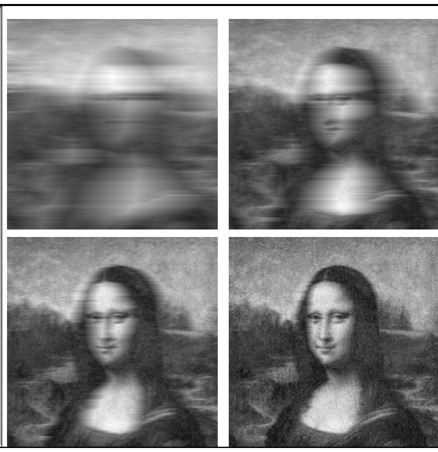
Problems



a b
c

FIGURE 8.22 An example of delta modulation.

Input		Encoder				Decoder		Error
n	f	$\hat{f}$	e	$\dot{e}$	$\dot{f}$	$\hat{f}$	$\dot{f}$	$[f - \dot{f}]$
0	14	—	—	—	14.0	—	14.0	0.0
1	15	14.0	1.0	6.5	20.5	14.0	20.5	–5.5
2	14	20.5	–6.5	–6.5	14.0	20.5	14.0	0.0
3	15	14.0	1.0	6.5	20.5	14.0	20.5	–5.5
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
14	29	20.5	8.5	6.5	27.0	20.5	27.0	2.0
15	37	27.0	10.0	6.5	33.5	27.0	33.5	3.5
16	47	33.5	13.5	6.5	40.0	33.5	40.0	7.0
17	62	40.0	22.0	6.5	46.5	40.0	46.5	15.5
18	75	46.5	28.5	6.5	53.0	46.5	53.0	22.0
19	77	53.0	24.0	6.5	59.6	53.0	59.6	17.5
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.



1 | 3

6.5 | 15

Transform Coding

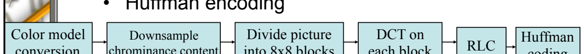
- Use discrete image transforms to transform the image
- Discard those coefficients that are near zero
- Coarsely quantize those coefficients that are small
- When reconstructed later, little important content will have been lost
- Example
  - JPEG (image lossy compression)
  - MPEG (video compression)

JPEG

- Joint Photographics Expert Group
- An image compression standard sanctioned by ISO
- can be very effectively applied to a 24-bit color image, achieving compression ratios of 10:1 to 20:1 without any image degradation that is visible to the human eye at normal magnification

JPEG Compression Steps

- Convert RGB model to intensity and chrominance (YIQ)
- Throw away half of the chrominance data
- Divide the pictures into blocks of 8x8 pixels
- Perform a discrete Cosine transform on each block
- Quantize the DCT coefficients
- Run-length encoding
- Huffman encoding



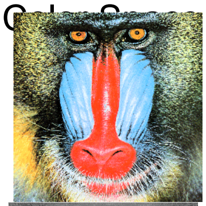
The YIQ Color Space

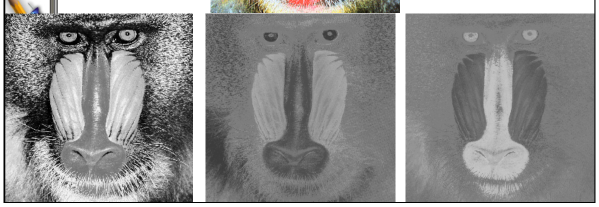
- Used in US commercial color television broadcasting
- Recoding of RGB for transmission efficiency and for downward compatibility with b/w television
- Y component: illuminance (gets the majority of the b/w)
- I, Q: chrominance

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- NTSC broadcast TV: 4.2MHz for Y, 1.5MHz for I, 0.55MHz for Q
- VCR: 3.2MHz for Y, 0.63 MHz for I.

YUV Color Space Example





Discrete Cosine Transform

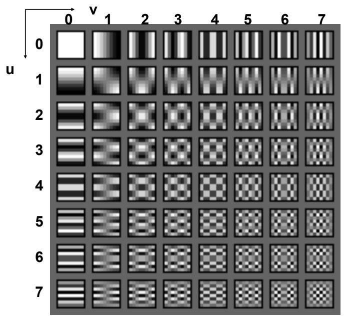
- Forward transform $T(u,v) = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)g(x,y,u,v)$

$$g(x,y,u,v) = \alpha(u)\alpha(v)\cos\left[\frac{(2x+1)u\pi}{2N}\right]\cos\left[\frac{(2y+1)v\pi}{2N}\right]$$

- Inverse transform $f(x,y) = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} T(u,v)h(x,y,u,v)$

$$g(x,y,u,v) = h(x,y,u,v)$$

The 64 DCT Basis Functions



http://www.it.cityu.edu.hk/~itaku/lecture/Chap4.2.html

DCT vs. DFT

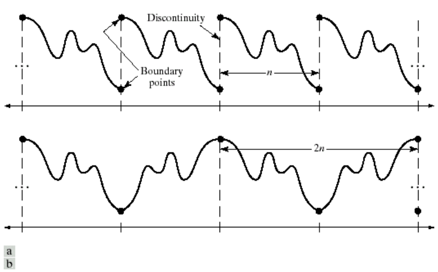


FIGURE 8.32 The periodicity implicit in the 1-D (a) DFT and (b) DCT.

Quantization

$$F'(u,v) = round\left(\frac{F(u,v)}{q(u,v)}\right)$$

Non-uniform quantization

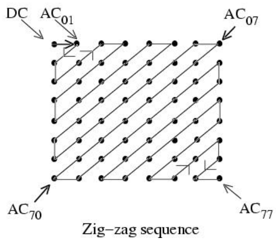
Luminance quantization table

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

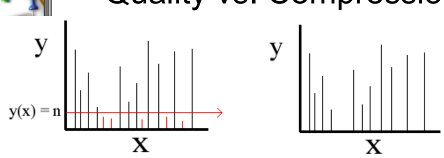
Zig-zag Scan and Huffman Coding

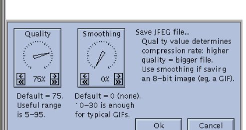


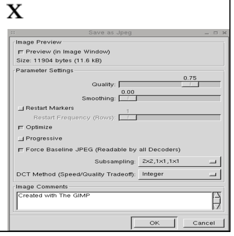
Use differential coding for DC and RLC for AC

Block Artifacts

Quality vs. Compression Ratio





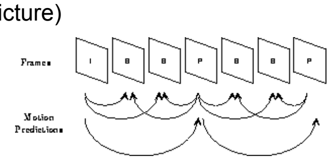


MPEG

- Motion Picture Experts Group
- Steps
  - Temporal redundancy reduction
  - Motion compensation
  - Spatial redundancy reduction
  - Entropy coding

Temporal Redundancy Reduction

- Three frames
  - I frame (intra picture)
  - P frame (predicted picture)
  - B frame (bidirectionally interpolated picture)



Motion Compensation

- Assume the current picture can be locally modeled as a translation of the pictures of some previous time.
- Each picture is divided into blocks of 16 x 16 pixels, called a macroblock.
- Each macroblock is predicted from the previous or future frame, by estimating the amount of the motion in the macroblock during the frame time interval.

Hardware Implementation

- High-speed hardware for JPEG and MPEG compression and decompression significantly reduces the computational overhead