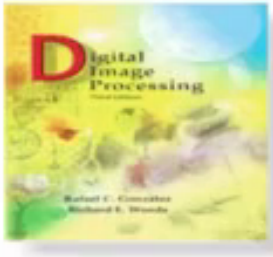
Why is Compression Needed?

$1000 \times 1000 \times 24 \times 30 \times 60 \times 120 =$

very large number



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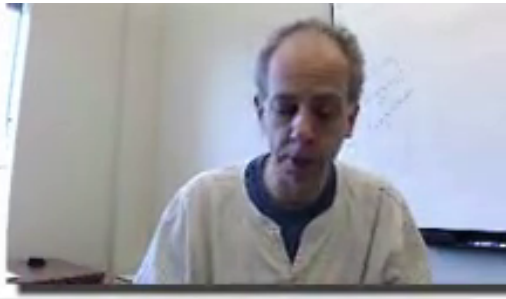
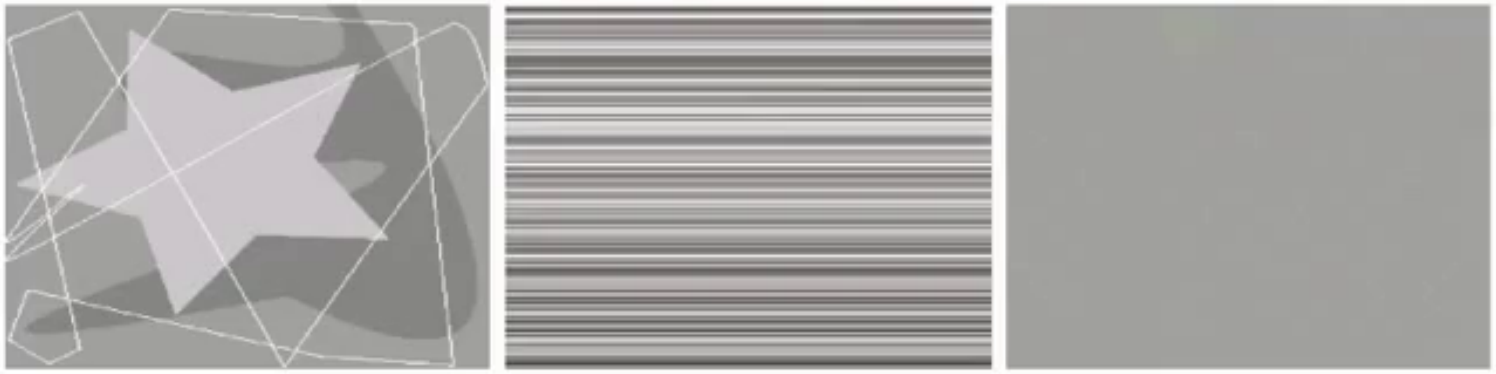


The reasons we can compress:



a b c

FIGURE 8.1 Computer generated 256 × 256 × 8 bit images with (a) coding redundancy, (b) spatial redundancy, and (c) irrelevant information. (Each was designed to demonstrate one principal redundancy but may exhibit others as well.)

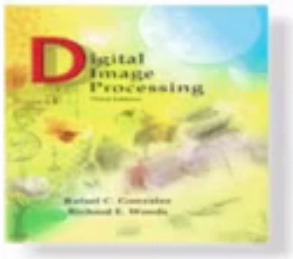


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Image Compression

Image Compression
Standards, Formats, and Containers

Still Image

Binary

CCITT Group 3
CCITT Group 4
JBIG (or JBIG1)
JBIG2

TIFF

Continuous Tone

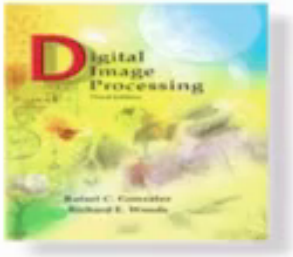
JPEG
JPEG-LS
JPEG-2000

BMP
GIF
PDF
PNG
TIFF

Video

DV
H.261
H.262
H.263
H.264
MPEG-1
MPEG-2
MPEG-4
MPEG-4 AVC

AVS
HDV
M-JPEG
QuickTime
VC-1 (or WMV9)



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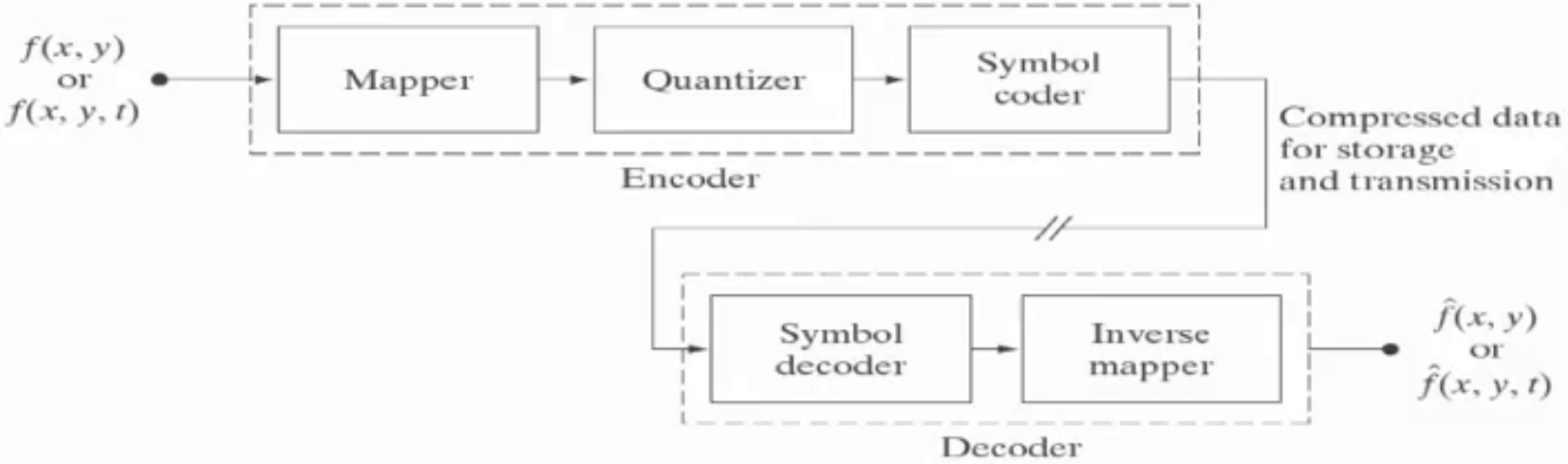

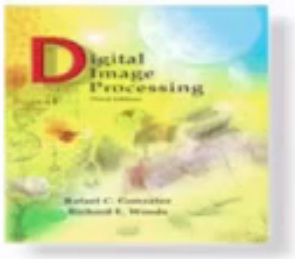

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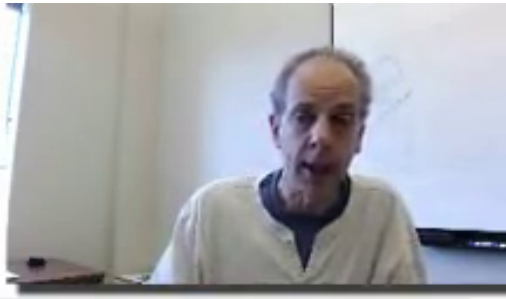
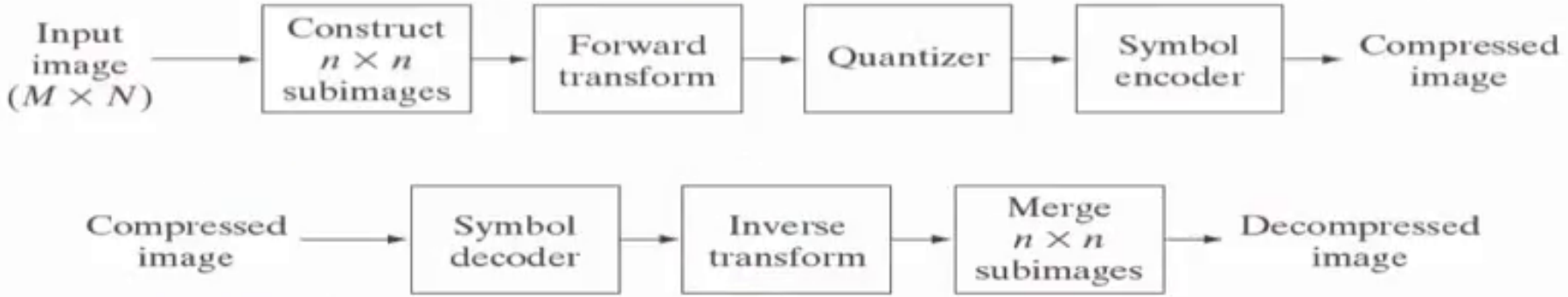
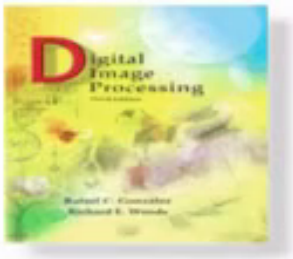


JPEG





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JPEG

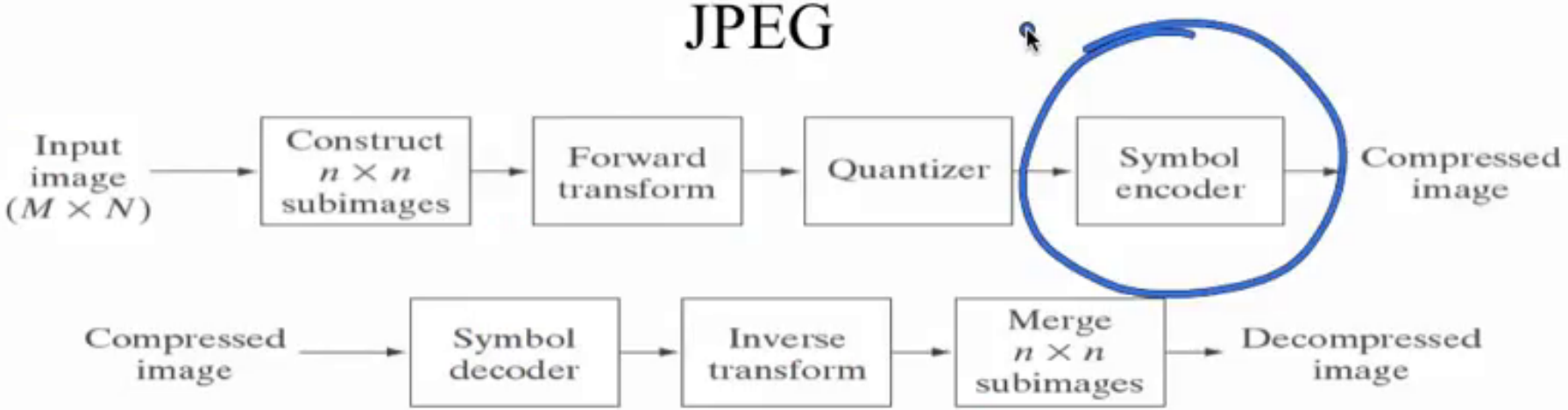

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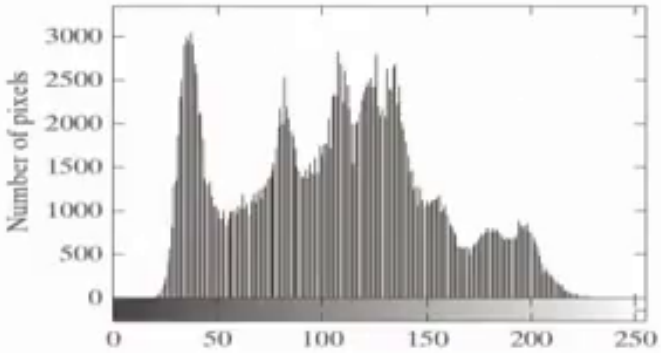
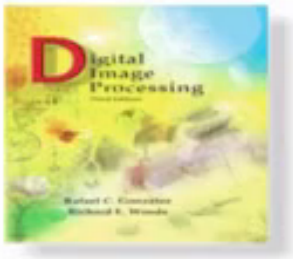
Image Compression

Are all pixels equal?





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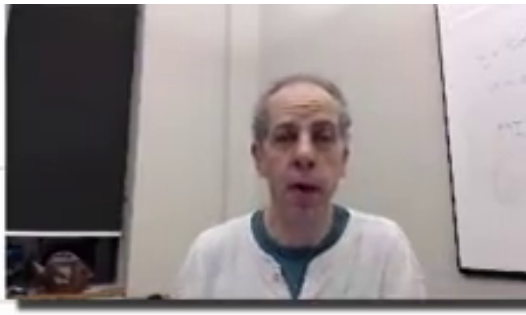
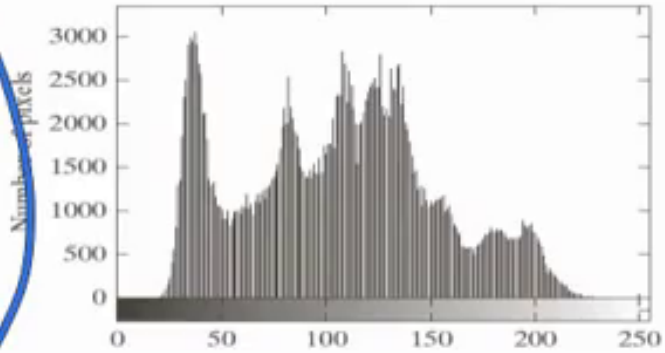
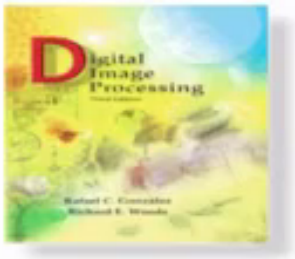


Are all pixels equal?



Lena

Histogram

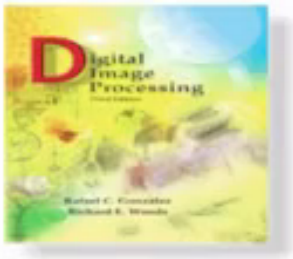


Chapter 8

Image Compression

Are all pixels/symbols equal?

r_k	$p_r(r_k)$	Code 1	$l_1(r_k)$	Code 2	$l_2(r_k)$
$r_{87} = 87$	0.25	01010111	8	01	2
$r_{128} = 128$	0.47	10000000	8	1	1
$r_{186} = 186$	0.25	11000100	8	000	3
$r_{255} = 255$	0.03	11111111	8	001	3
r_k for $k \neq 87, 128, 186, 255$	0	—	8	—	0



Chapter 8

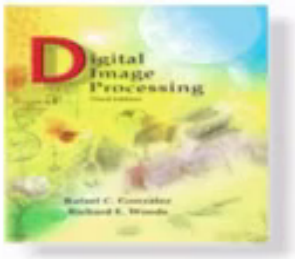
Image Compression

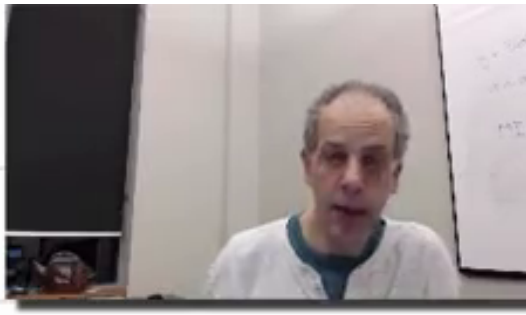
Are all pixels/symbols equal?

r_k	$p_r(r_k)$	Code 1	$l_1(r_k)$	Code 2	$l_2(r_k)$
$r_{87} = 87$	0.25	01010111	8	01	2
$r_{128} = 128$	0.47	10000000	8	1	1
$r_{186} = 186$	0.25	11000100	8	000	3
$r_{255} = 255$	0.03	11111111	8	001	3
r_k for $k \neq 87, 128, 186, 255$	0	—	8	—	0

$0.25 \times 2 + 0.47 \times 1 + 0.25 \times 3 + 0.03 \times 3 =$

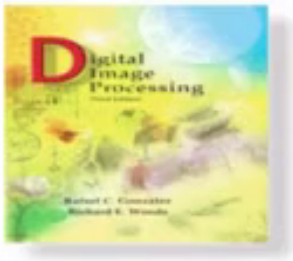
1.81





Huffman Coding

Original source		Source reduction			
Symbol	Probability	1	2	3	4
a_2	0.4	0.4	0.4	0.4	0.6
a_6	0.3	0.3	0.3	0.3	0.4
a_1	0.1	0.1	0.2	0.3	
a_4	0.1	0.1	0.1		
a_3	0.06	0.1			
a_5	0.04				



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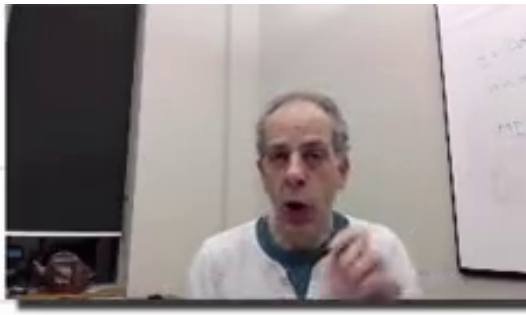

Original source			Source reduction							
Symbol	Probability	Code	1		2		3		4	
a_2	0.4	1	0.4	1	0.4	1	0.4	1	0.6	0
a_6	0.3	00	0.3	00	0.3	00	0.3	00	0.4	1
a_1	0.1	011	0.1	011	0.2	010	0.3	01		
a_4	0.1	0100	0.1	0100	0.1	011				
a_3	0.06	01010	0.1	0101						
a_5	0.04	01011								

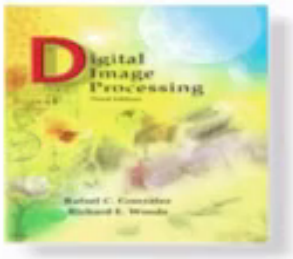

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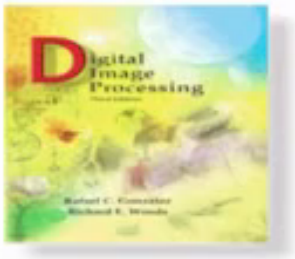
Image Compression

Original source			Source reduction							
Symbol	Probability	Code	1		2		3		4	
a_2	0.4	1	0.4	1	0.4	1	0.4	1	0.6	0
a_6	0.3	00	0.3	00	0.3	00	0.3	00	0.4	1
a_1	0.1	011	0.1	011	0.2	010	0.3	01		
a_4	0.1	0100	0.1	0100	0.1	011				
a_3	0.06	01010	0.1	0101						
a_5	0.04	01011								

$$\text{Entropy} = H = -\sum_{\text{symbols}} p(s) \log_2 p(s)$$



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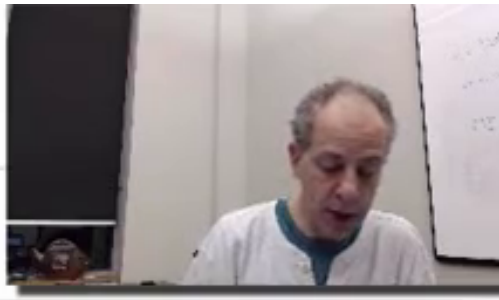
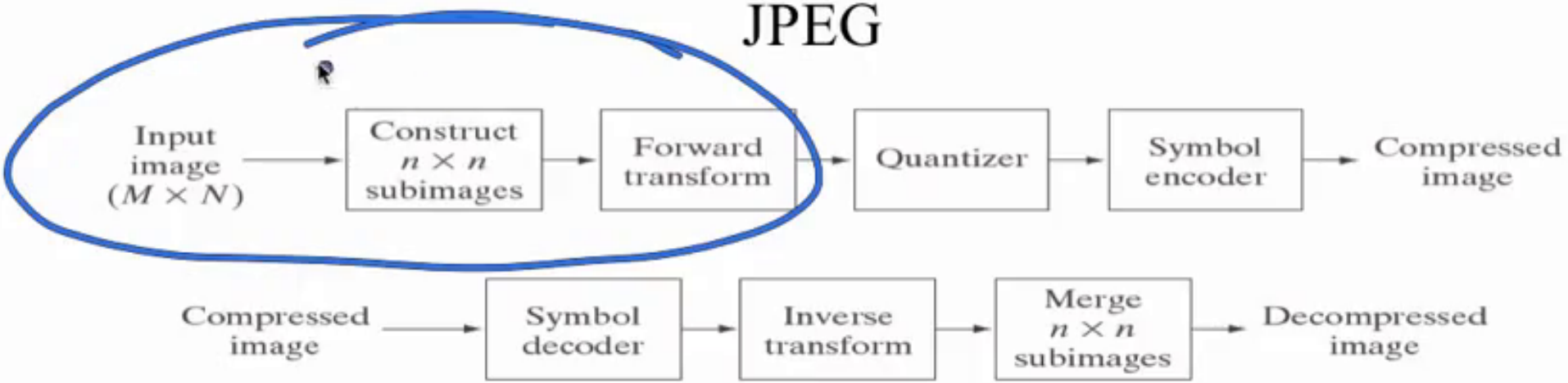
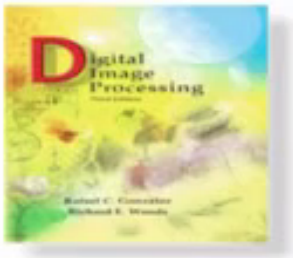


JPEG





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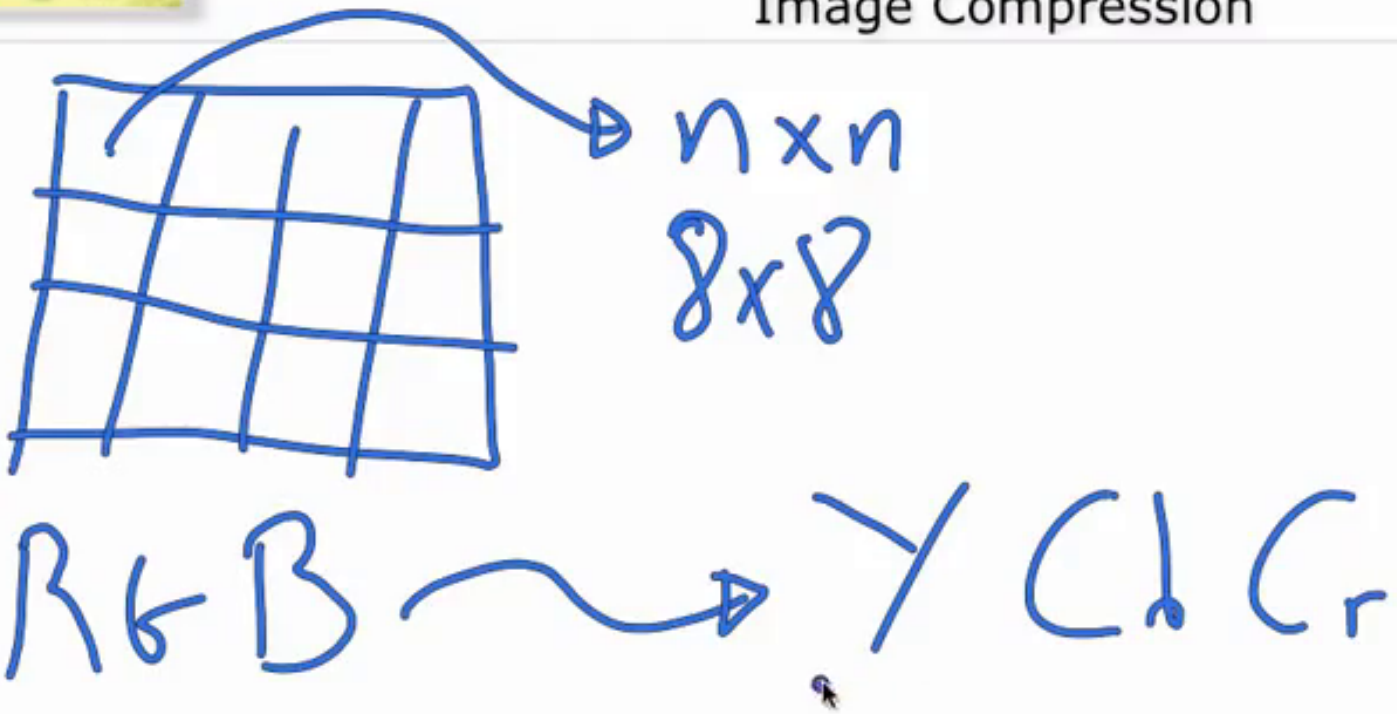

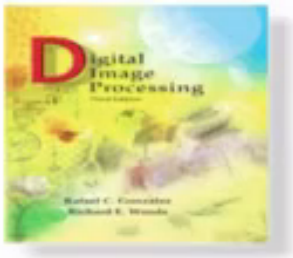

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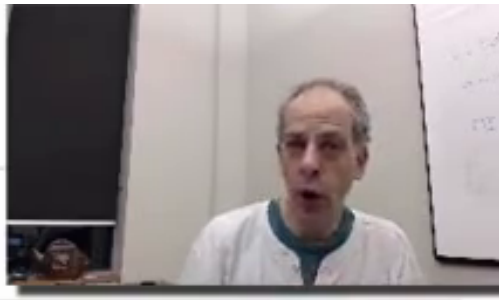

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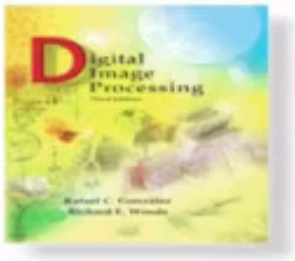

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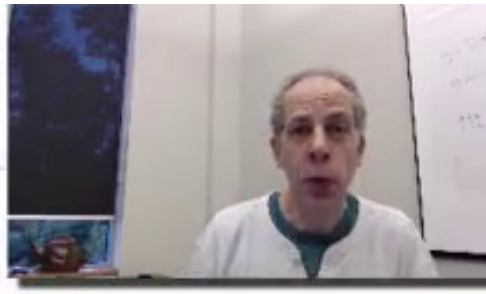

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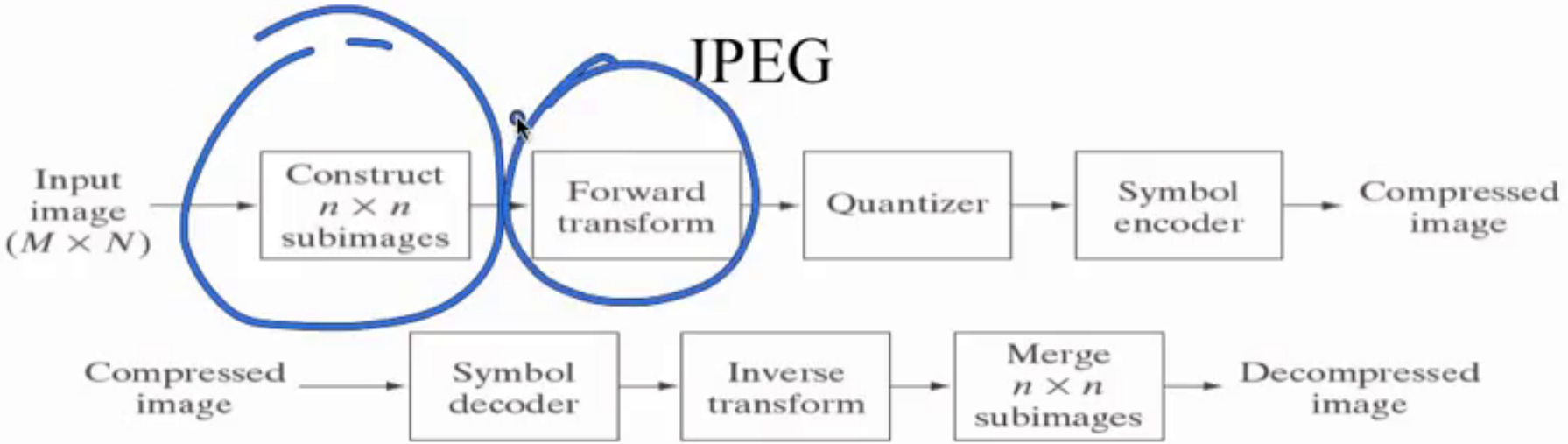
Image Compression



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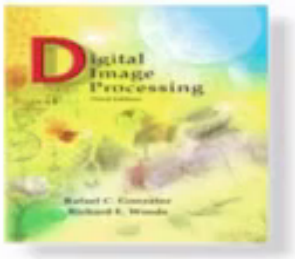

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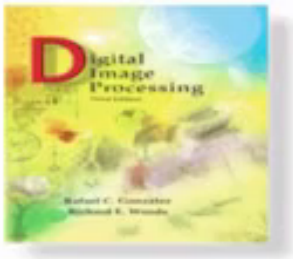
Image Compression

MSE = Mean Square Error

$$MSE = \left[\frac{1}{\text{\# of pixels}} \sum_{\text{pixels}} (\hat{f} - f)^2 \right]^{1/2}$$

n x n Kahunen-Loève

KLT



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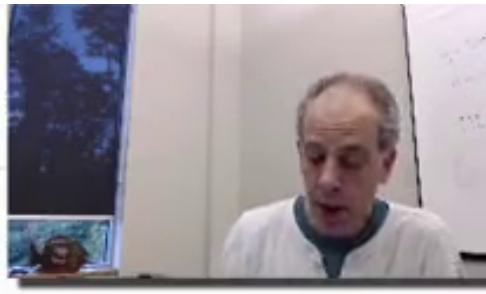


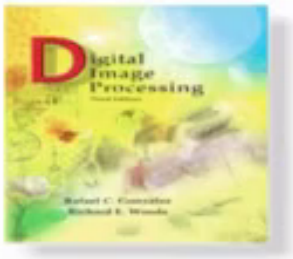
Chapter 8

Image Compression

$$T(u,v) = \sum_{x=0}^{n-1} \sum_{y=0}^{n-1} f(x,y)\, r(x,y,u,v)$$

$n \times n$

$$f(x,y) = \sum_{u=0}^{n-1} \sum_{v=0}^{n-1} T(u,v)\, s(x,y,u,v)$$



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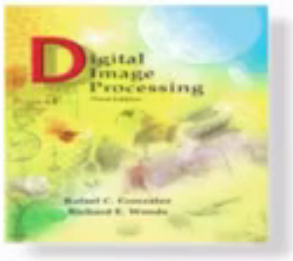
$$r(x,y,u,v) = s(x,y,u,v)$$

$$= \alpha(u)\alpha(v)\cos\left[\frac{(2x+1)u\pi}{2n}\right] \cdot$$

$$\alpha(u) = \begin{cases} \sqrt{\frac{1}{n}} & u = 0 \\ \sqrt{\frac{2}{n}} & u \neq 0 \end{cases} \qquad \cos\left[\frac{(2y+1)v\pi}{2n}\right]$$

DCT



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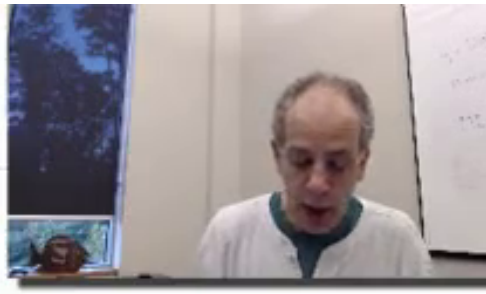

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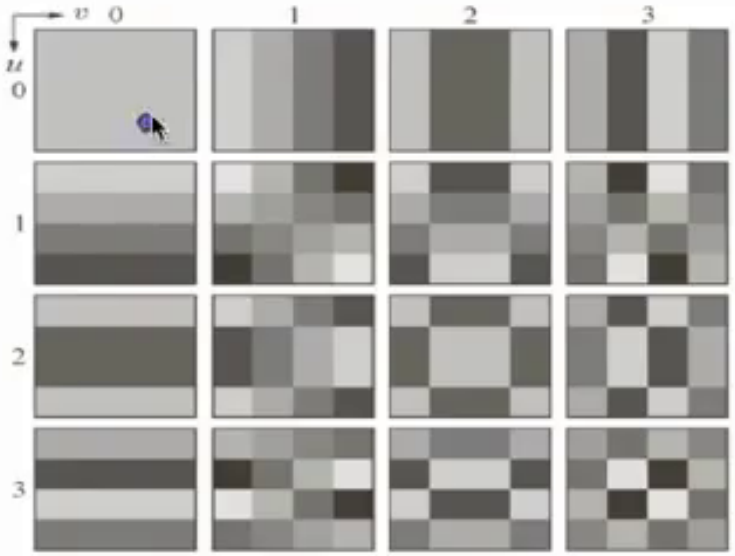
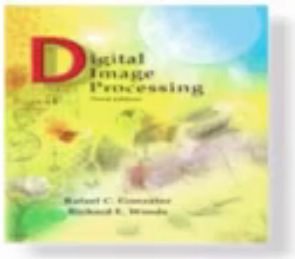
Discrete Cosine Transform



n=4



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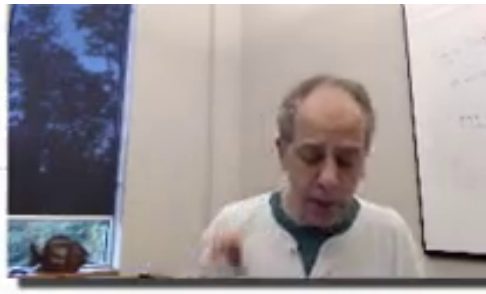
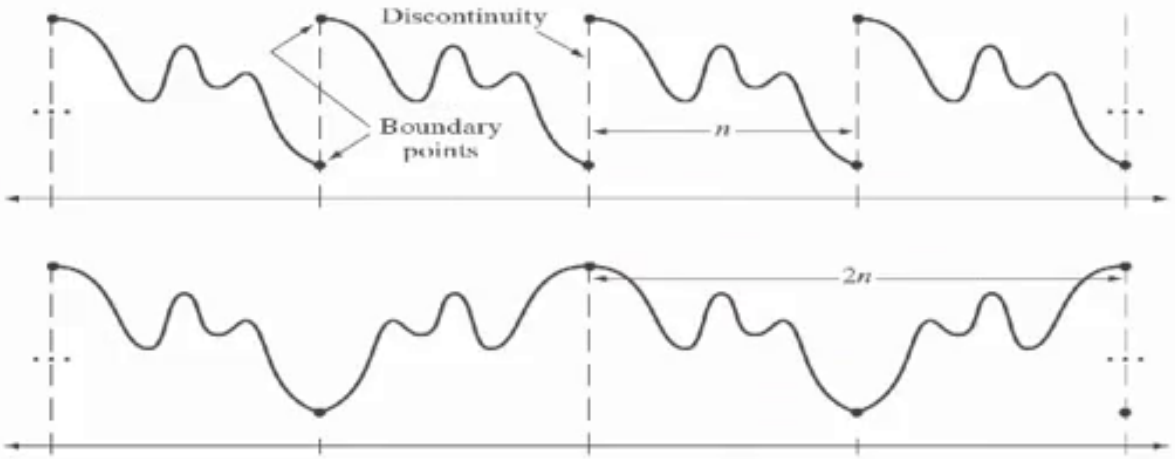
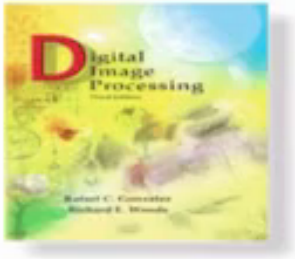


Why DCT?





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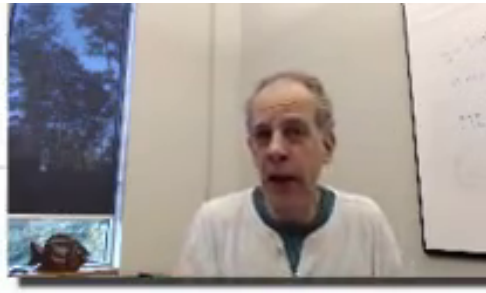

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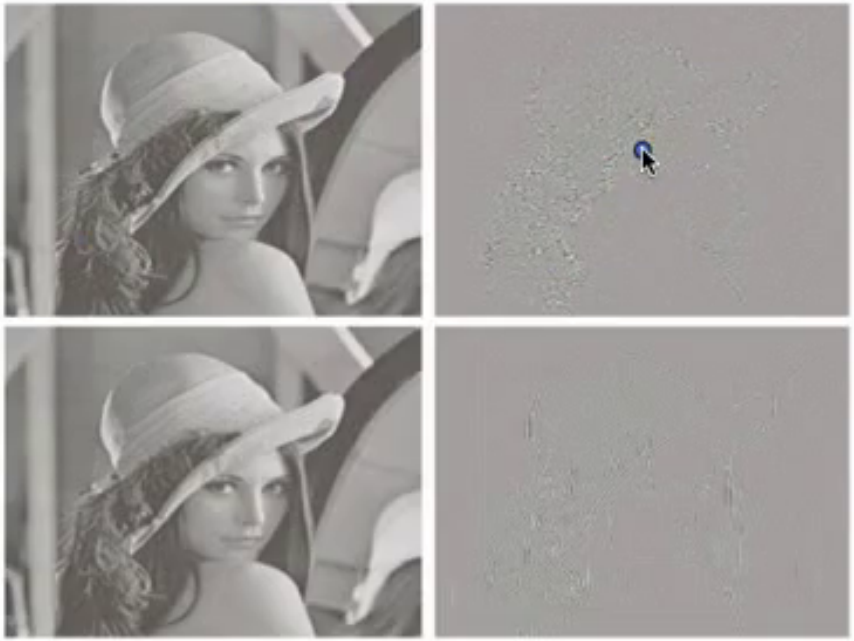
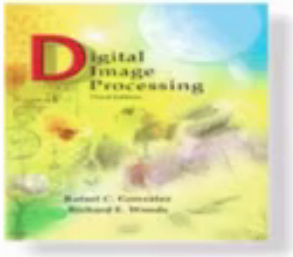
Image Compression



a b
c d

FIGURE 8.28 Approximations of Fig. 8.9(a) using 12.5% of the 8×8 DCT coefficients: (a)—(b) threshold coding results; (c)—(d) zonal coding results. The difference images are scaled by 4.



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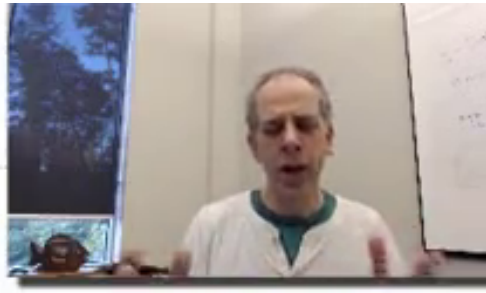

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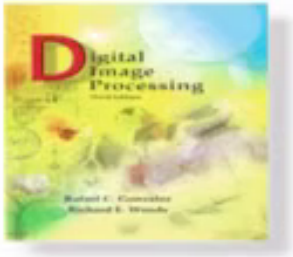
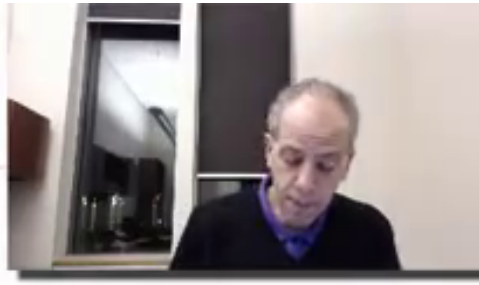
a b c d

FIGURE 8.27 Approximations of Fig. 8.27(a) using 25% of the DCT coefficients and (b) 2×2 subimages, (c) 4×4 subimages, and (d) 8×8 subimages. The original image in (a) is a zoomed section of Fig. 8.9(a).





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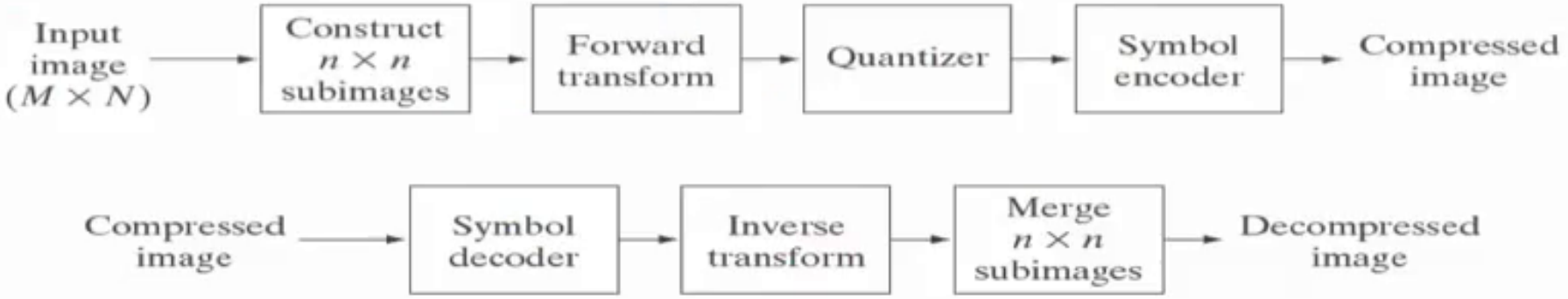
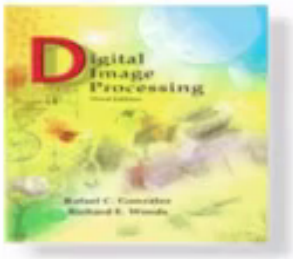
JPEG





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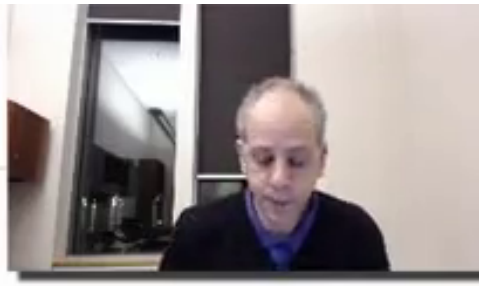

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1	1	1	1	1	0	0	0
1	1	1	1	0	0	0	0
1	1	1	0	0	0	0	0
1	1	0	0	0	0	0	0
1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

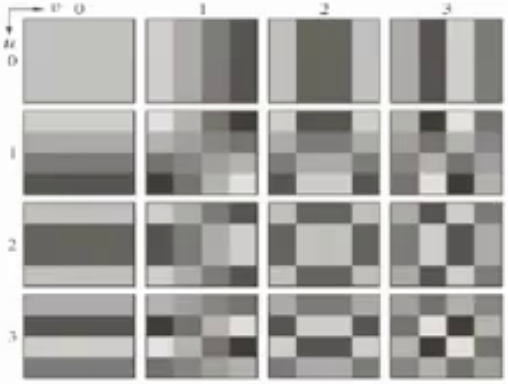
8	7	6	4	3	2	1	0
7	6	5	4	3	2	1	0
6	5	4	3	3	1	1	0
4	4	3	3	2	1	0	0
3	3	3	2	1	1	0	0
2	2	1	1	1	0	0	0
1	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0

1	1	0	1	1	0	0	0
1	1	1	1	0	0	0	0
1	1	0	0	0	0	0	0
1	0	0	0	0	0	0	0
0	0	0	0	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	1	5	6	14	15	27	28
2	4	7	13	16	26	29	42
3	8	12	17	25	30	41	43
9	11	18	24	31	40	44	53
10	19	23	32	39	45	52	54
20	22	33	38	46	51	55	60
21	34	37	47	50	56	59	61
35	36	48	49	57	58	62	63

a b
c d

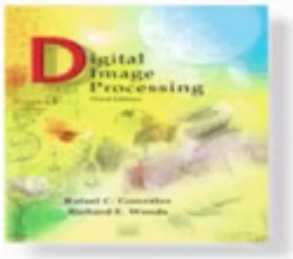
FIGURE 8.29 A typical (a) zonal mask, (b) zonal bit allocation, (c) threshold mask, and (d) thresholded coefficient ordering sequence. Shading highlights the coefficients that are retained.



$$T(u,v) = \sum_x \sum_y f(x,y)\, r(x,y,u,v)$$

$$\hat{f}(x,y) = \sum_u \sum_v \hat{T}(u,v)\, r(x,y,u,v)$$

$\hat{T}(0,0)$ $\hat{T}(0,1)$ $\hat{T}(1,0)$



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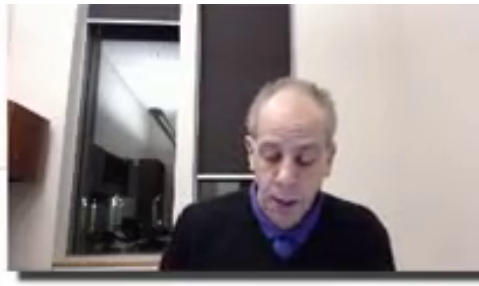

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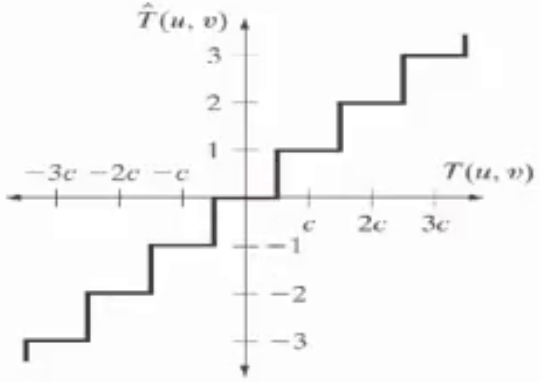

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

a b

FIGURE 8.30 (a) A threshold coding quantization curve [see Eq. (8.2-29)]. (b) A typical normalization matrix.

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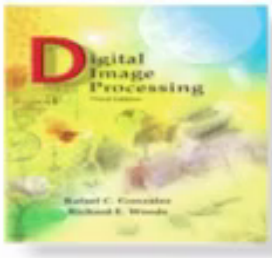

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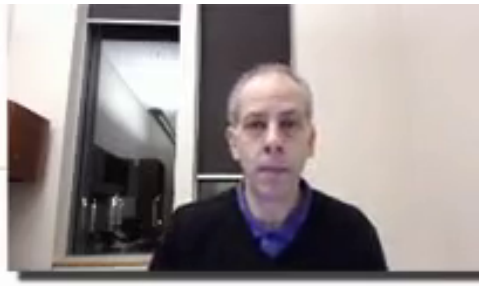

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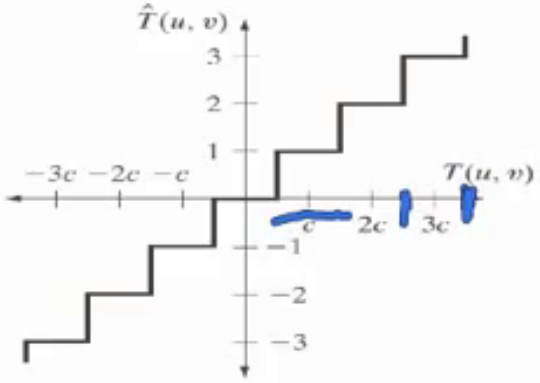


16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

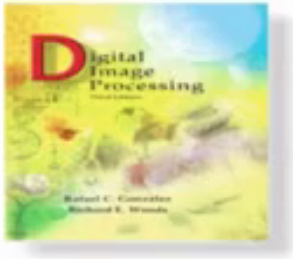
a b

FIGURE 8.30 (a) A threshold coding quantization curve [see Eq. (8.2-29)]. (b) A typical normalization matrix.

$$\left[\frac{T(0,10)}{16}\right] \times 16 \simeq \hat{T}(0,10)$$

$$0..15 \simeq 0$$

$$16..31 \simeq 1$$



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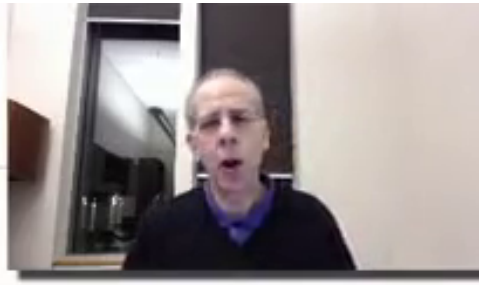

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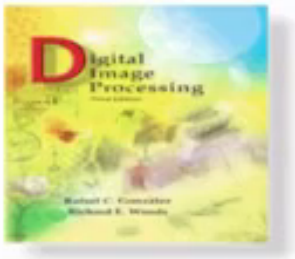
52	55	61	66	70	61	64	73
63	59	66	90	109	85	69	72
62	59	68	113	144	104	66	73
63	58	71	122	154	106	70	69
67	61	68	104	126	88	68	70
79	65	60	70	77	63	58	75
85	71	64	59	55	61	65	83
87	79	69	68	65	76	78	94

EXAMPLE 8.17: JPEG baseline coding and decoding.



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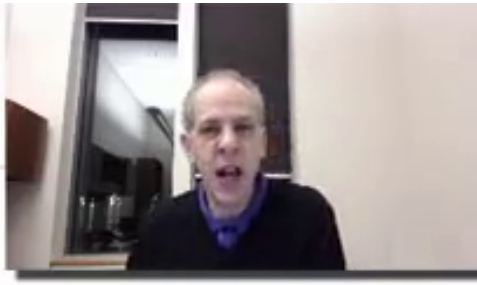

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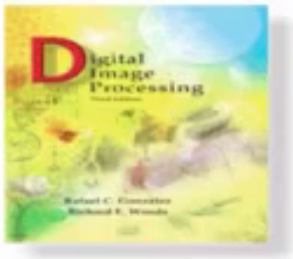
FIGURE 8.31 Approximations of Fig. 8.9(a) using the DCT and normalization array of Fig. 8.30(b): (a) $\mathbf{Z}$, (b) $2\mathbf{Z}$, (c) $4\mathbf{Z}$, (d) $8\mathbf{Z}$, (e) $16\mathbf{Z}$, and (f) $32\mathbf{Z}$.



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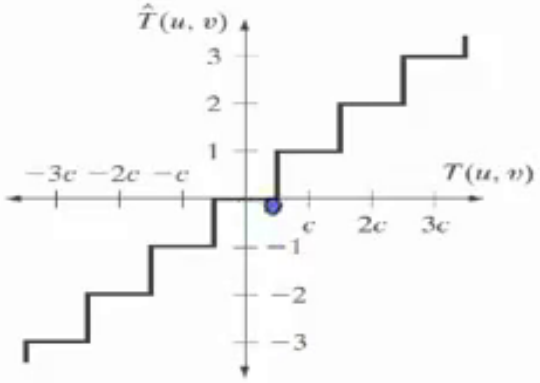
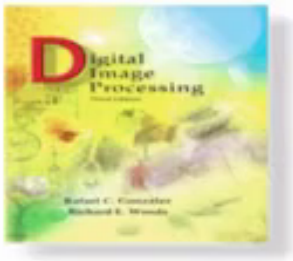


16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

a b

FIGURE 8.30 (a) A threshold coding quantization curve [see Eq. (8.2-29)]. (b) A typical normalization matrix.



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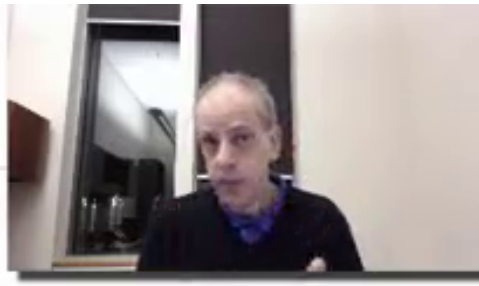

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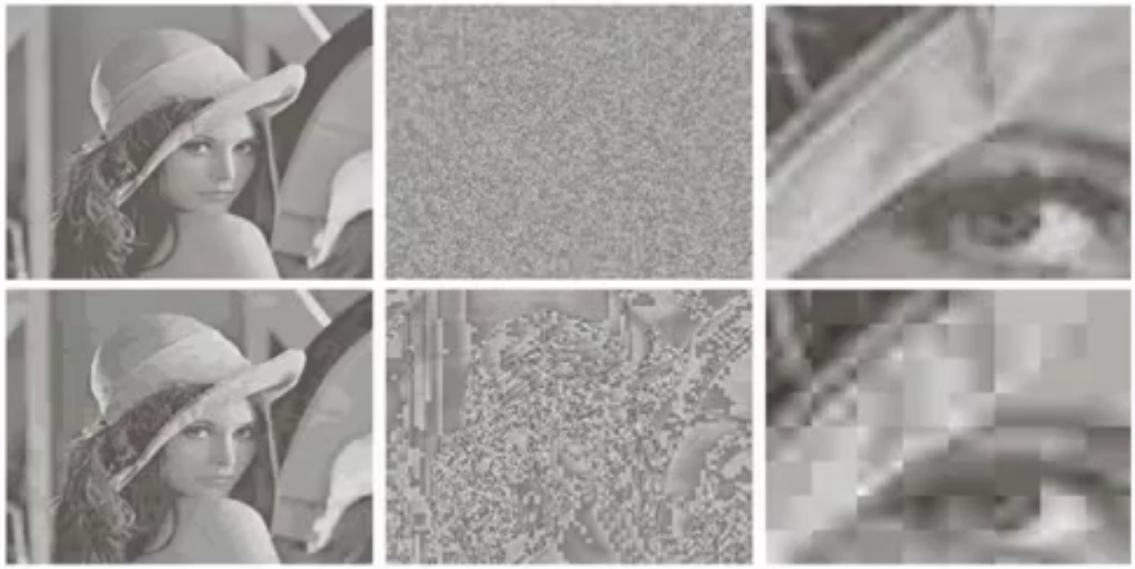
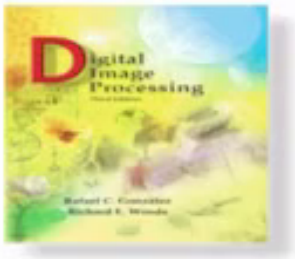


a b c
d e f

FIGURE 8.32 Two JPEG approximations of Fig. 8.9(a). Each row contains a result after compression and reconstruction, the scaled difference between the result and the original image, and a zoomed portion of the reconstructed image.



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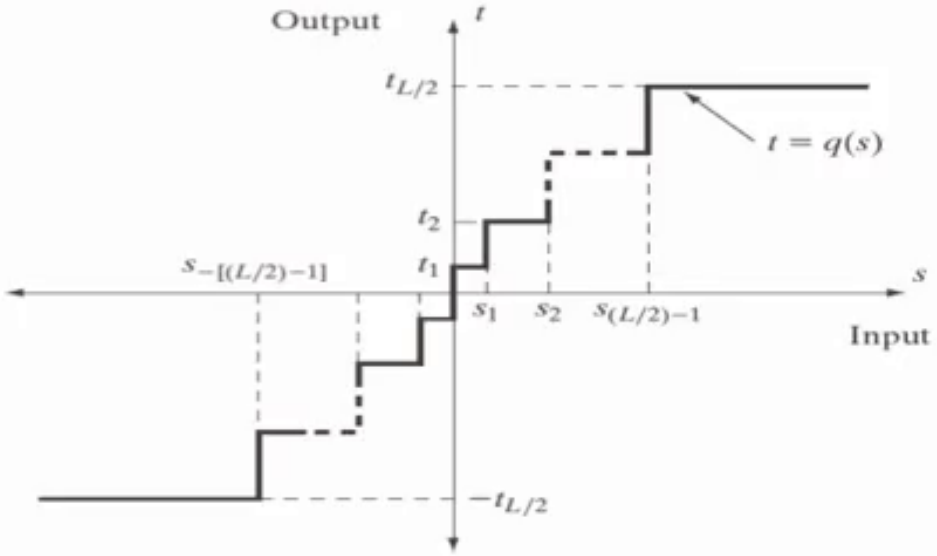
Max-Lloyd Optimal Quantizer

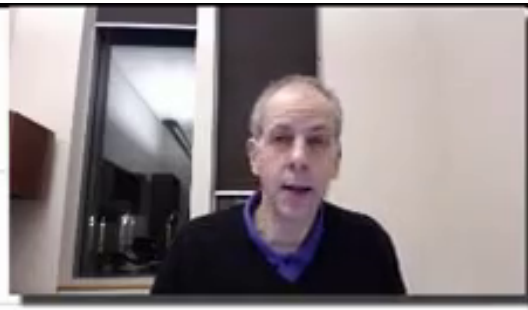


Error

$(s_i - t_i)^2$

$$\int_{s_{i-1}}^{s_i} (s_i - t_i)\, p(s)\, ds$$

s_i – average t_i, t_{i+1}



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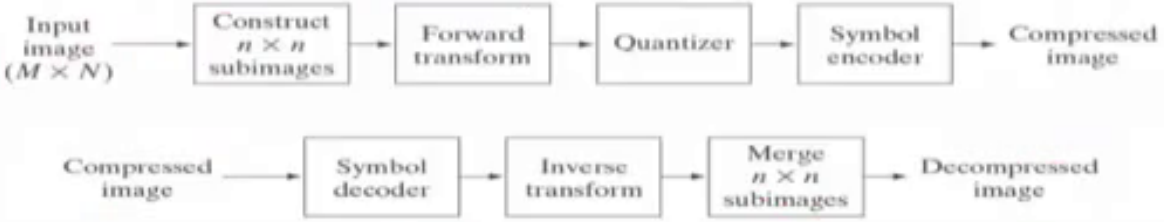
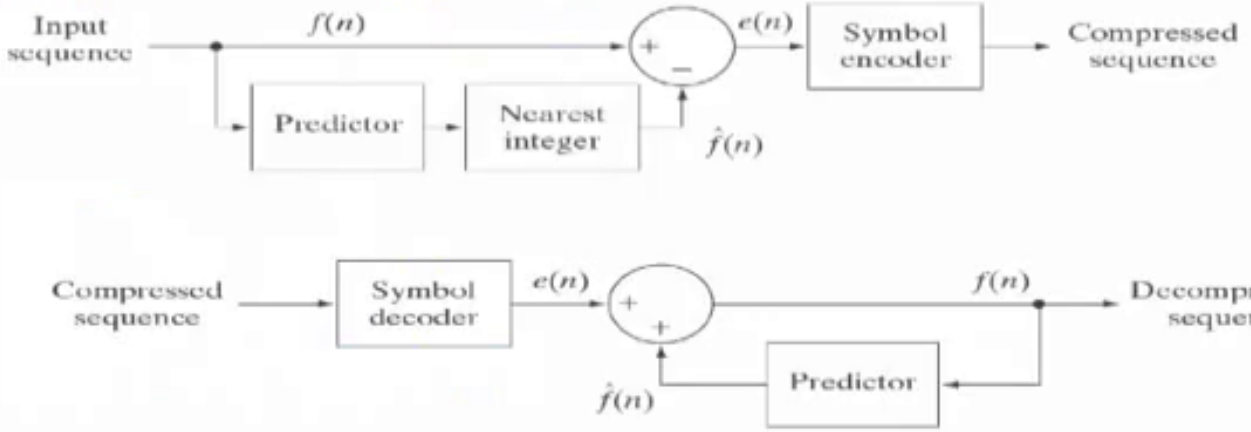
Predictive lossless compression





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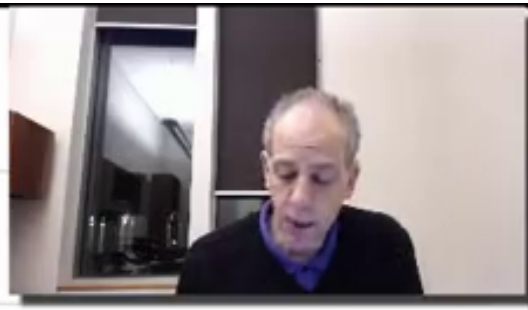

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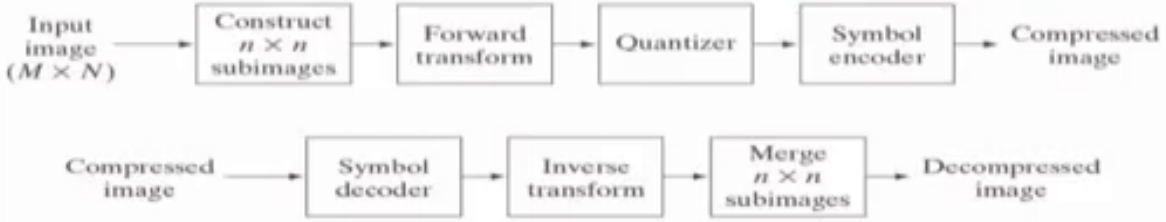
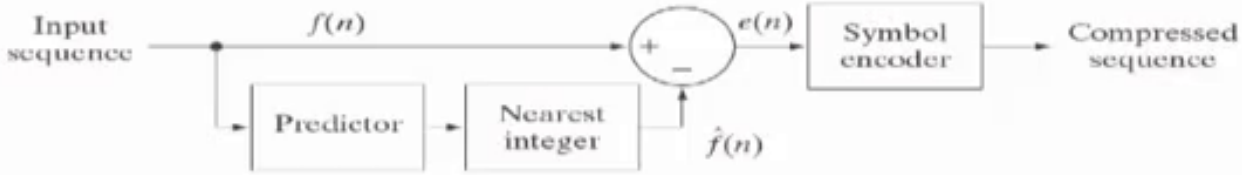
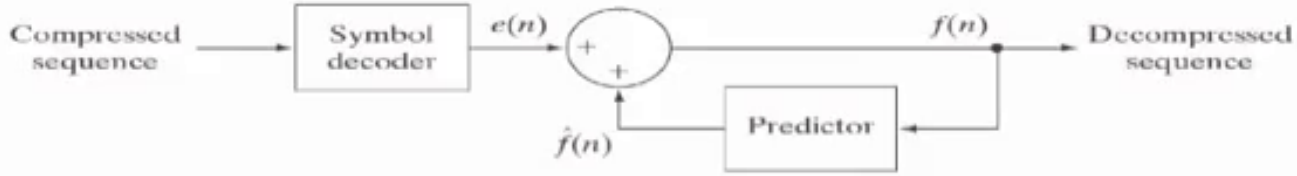
Predictive lossless compression







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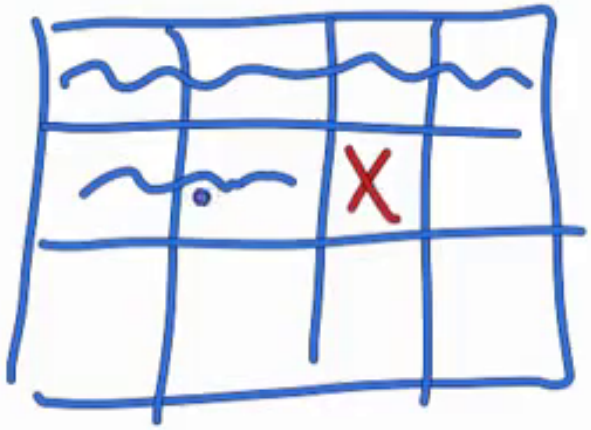
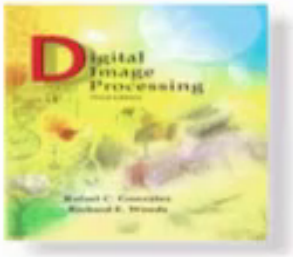
Examples of predictors and JPEG-LS



$f(x-1,y)$

$e = f(x-1,y) - f(x,y)$



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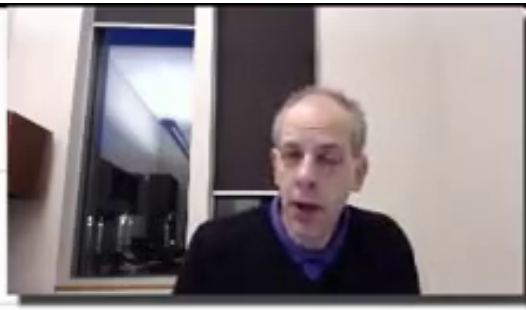

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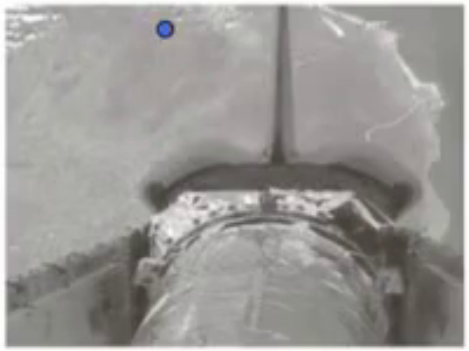

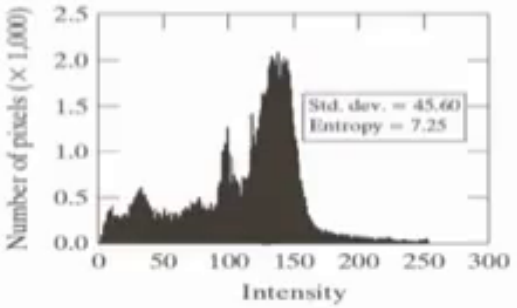

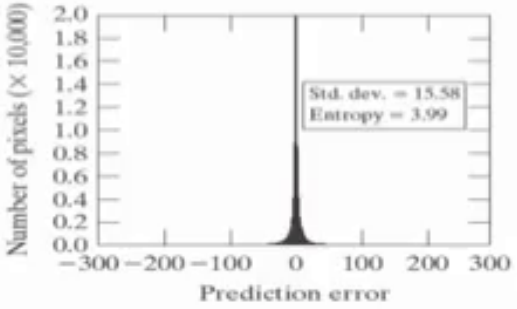

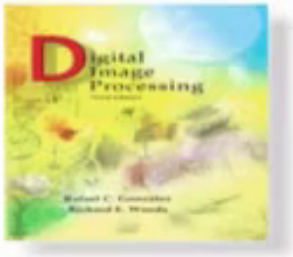

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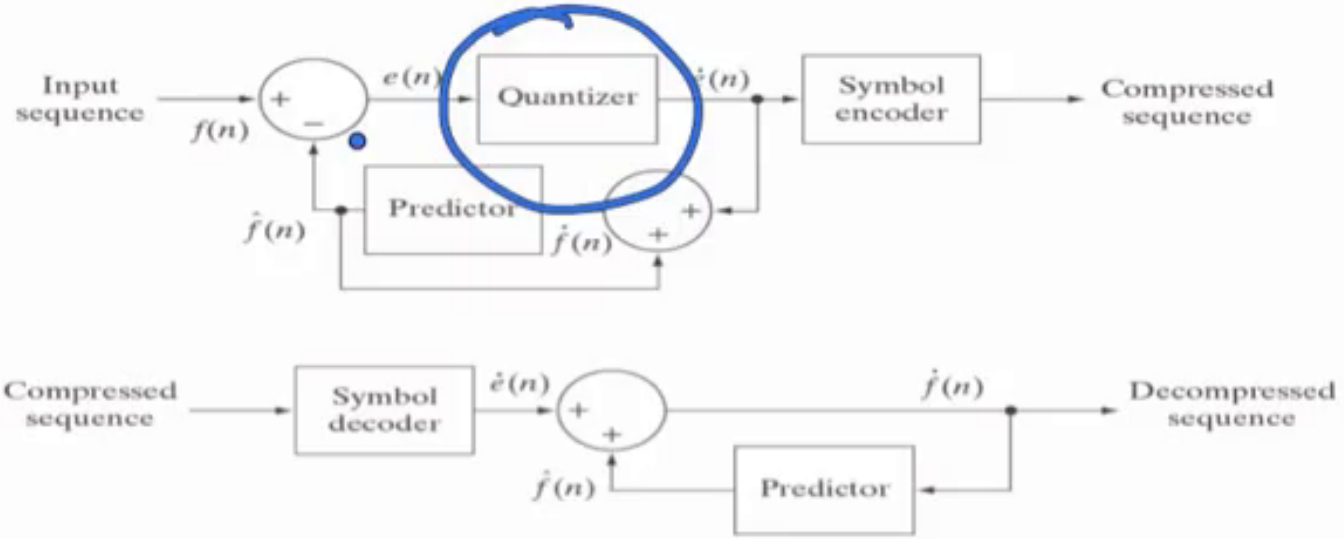
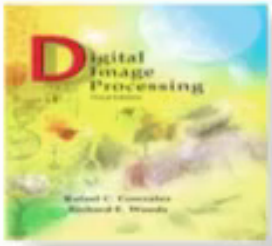


a
b

FIGURE 8.41
A lossless predictive coding model: (a) encoder; (b) decoder.



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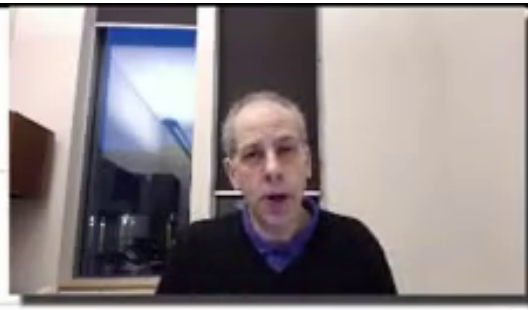

Temporal prediction (MPEG)

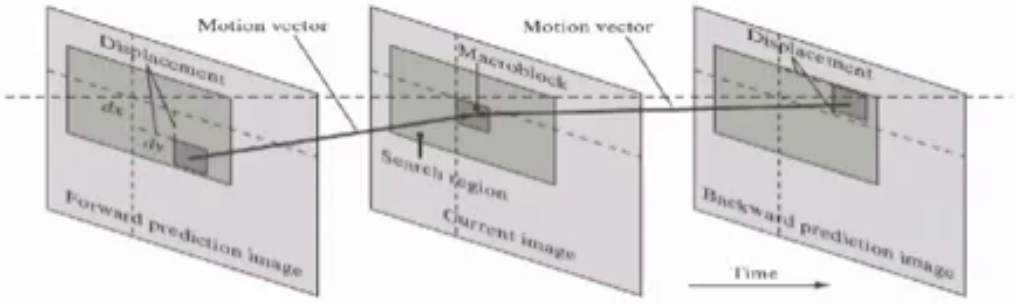

FIGURE 8.36 Macroblock motion specification.

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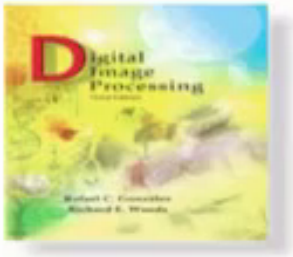

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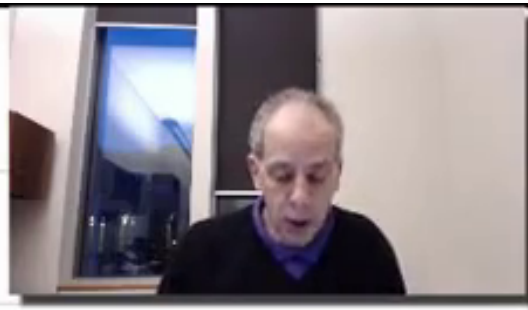

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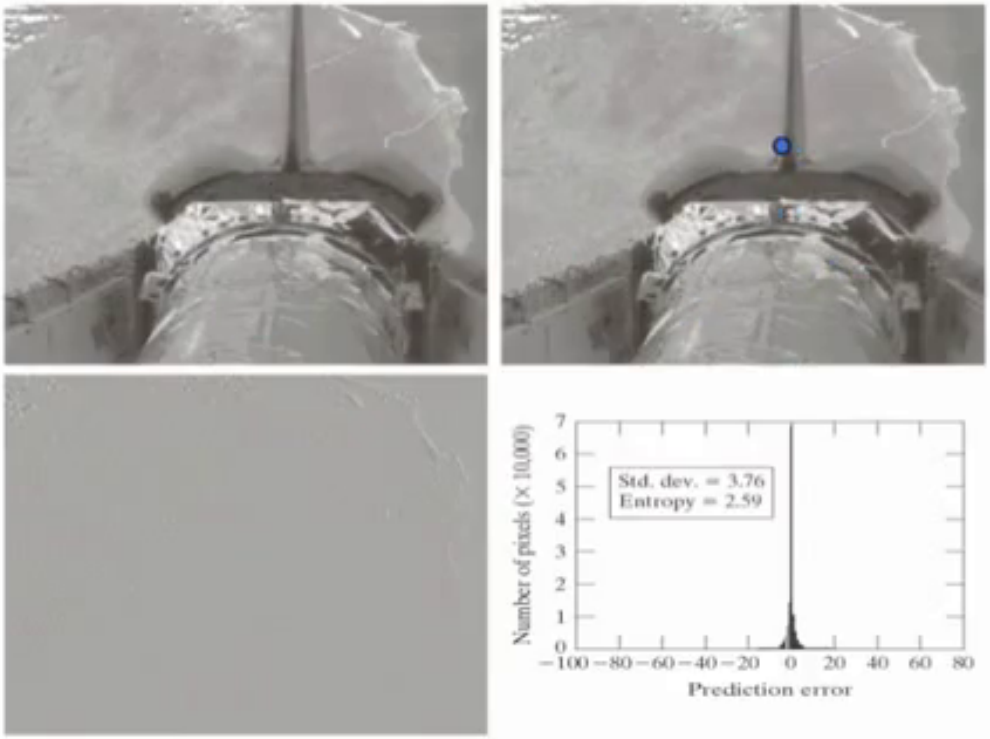
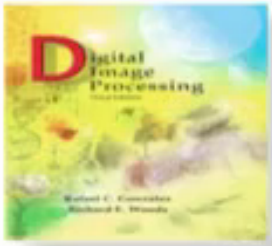
Image Compression

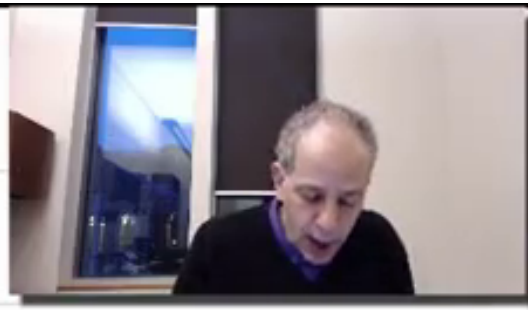




Digital Image Processing, 3rd ed.

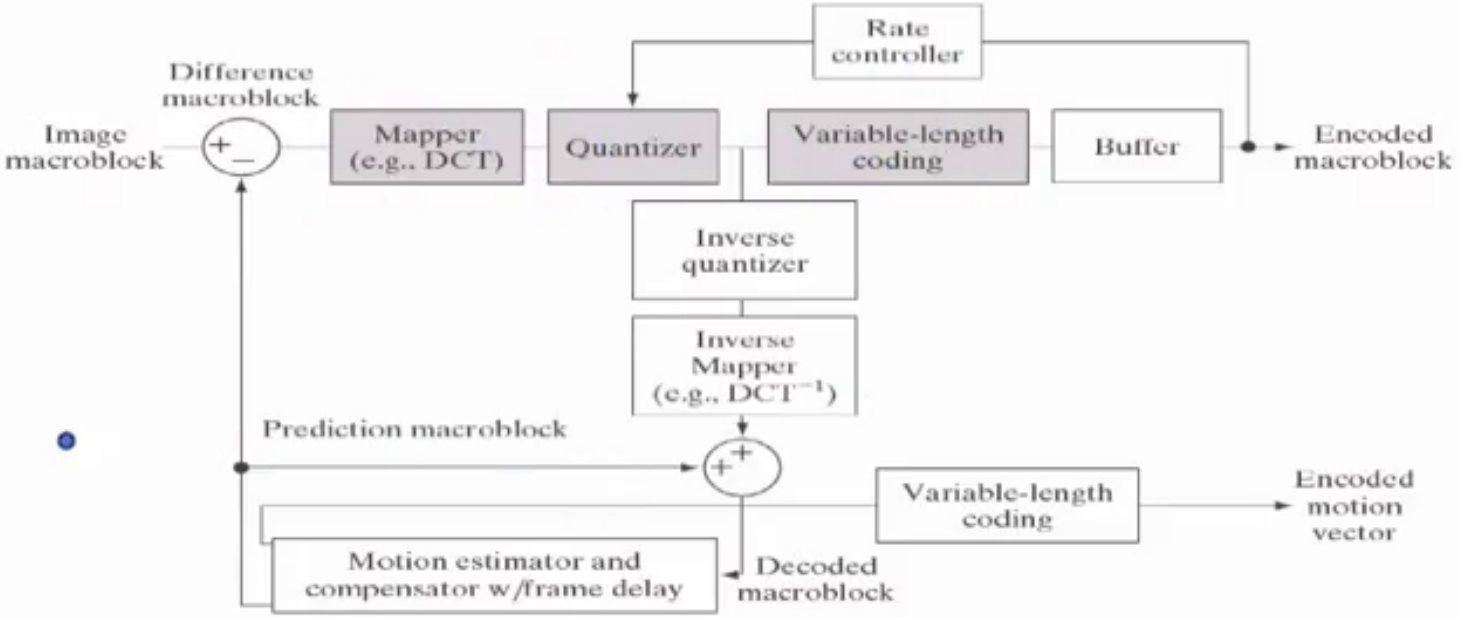
Gonzalez & Woods

www.ImageProcessingPlace.com

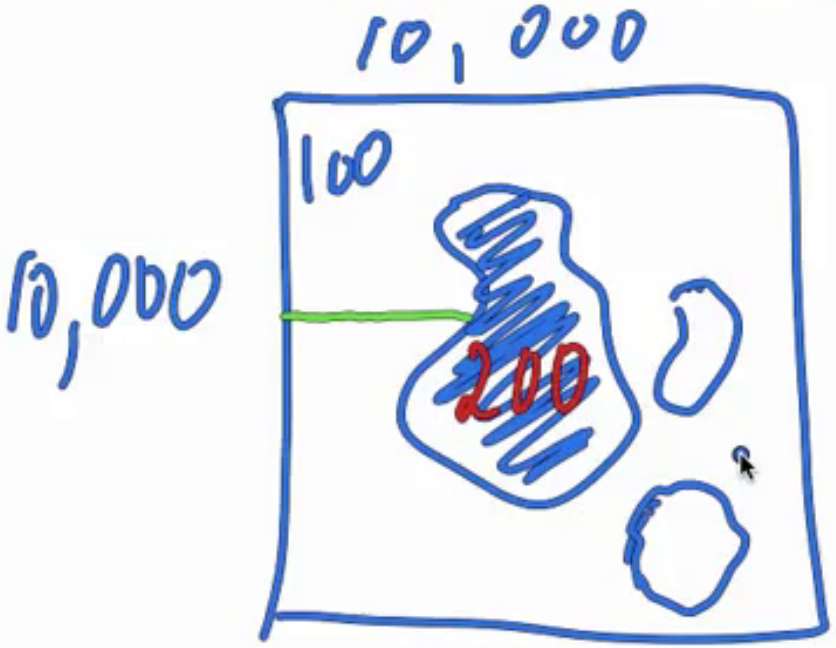


Chapter 8

Image Compression



Bonus: Run-length Coding



3000, 1000