IMAGE COMPRESSION

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M.tech,Semester-II

Image Compression?

- The problem of reducing the amount of data required to represent a digital image.

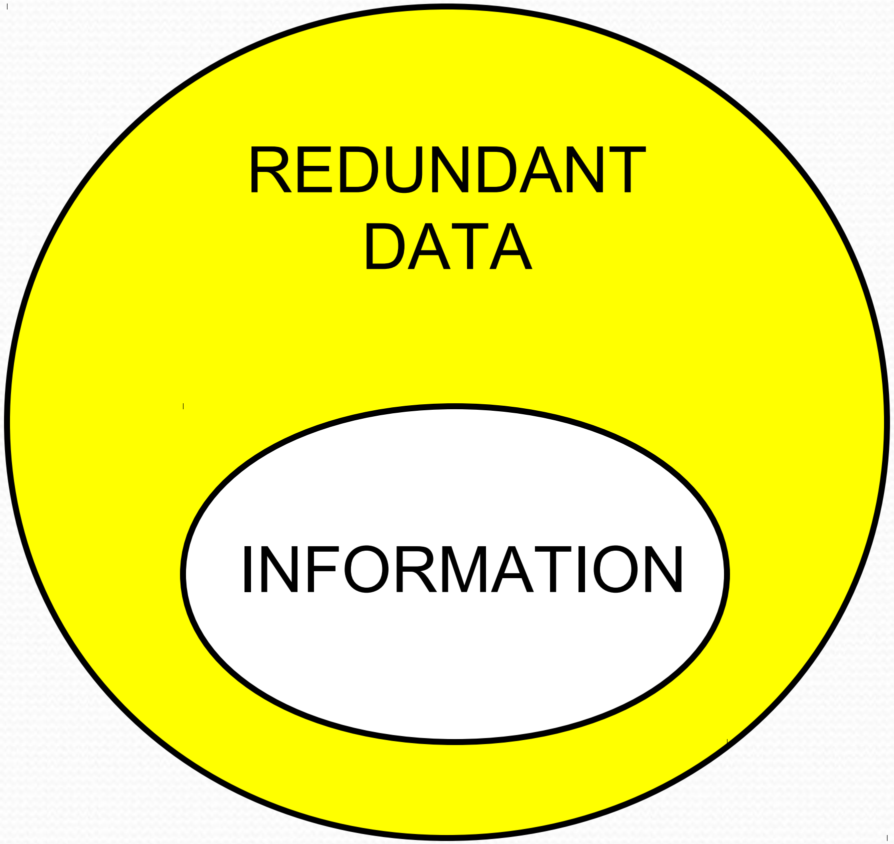
- From a mathematical viewpoint: transforming a 2-D pixel array into a statistically uncorrelated data set.

Why do We Need Compression?

- For data STORAGE and data TRANSMISSION
  - DVD
  - Remote Sensing
  - Video conference
  - FAX
  - Control of remotely piloted vehicle

- The bit rate of uncompressed digital cinema data exceeds one Gbps.

Information vs Data



DATA = INFORMATION + REDUNDANT DATA

Why Can We Compress?

- Spatial redundancy
  - Neighboring pixels are not independent but correlated

- Temporal redundancy

Fundamentals

- Basic data redundancies:
  1. Coding redundancy
  2. Inter-pixel redundancy
  3. Psycho-visual redundancy

Coding Redundancy

Let us assume, that a discrete random variable r_k in the interval [0,1] represent the gray level of an image:

$$p_r(r_k) = \frac{n_k}{n} \qquad k = 0, 1, 2, \cdots, L-1$$

If the number of bits used to represent each value of r_k is $l(r_k)$, then the average number of bits required to represent each pixel:

$$L_{avg} = \sum_{k=0}^{L-1} l(r_k) p_r(r_k)$$

The total number bits required to code an *MxN* image:

$$M.N.L_{avg}$$

Coding Redundancy

r_k	$p_r(r_k)$	Code 1	$l_1(r_k)$	Code 2	$l_2(r_k)$
$r_0 = 0$	0.19	000	3	11	2
$r_1 = 1/7$	0.25	001	3	01	2
$r_2 = 2/7$	0.21	010	3	10	2
$r_3 = 3/7$	0.16	011	3	001	3
$r_4 = 4/7$	0.08	100	3	0001	4
$r_5 = 5/7$	0.06	101	3	00001	5
$r_6 = 6/7$	0.03	110	3	000001	6
$r_7 = 1$	0.02	111	3	000000	6

TABLE 8.1 Example of variable-length coding.

$$
\begin{aligned}
L_{avg} &= \sum_{k=0}^{7} l_2(r_k)\, p_r(r_k) \\
&= 2(0.19) + 2(0.25) + 2(0.21) + 3(0.16) + 4(0.08) \\
&\quad + 5(0.06) + 6(0.03) + 6(0.02) \\
&= 2.7\, bits
\end{aligned}
$$

Compression ratio: $C_R = \dfrac{n_1}{n_2}$

Relative data redundancy: $R_d = 1 - \dfrac{1}{C_R}$

$$C_R = \frac{3}{2.7} = 1.11 \qquad R_d = 1 - \frac{1}{1.11} = 0.099$$

Inter-pixel Redundancy

Here the two pictures have

Approximately the same

Histogram.

We must exploit Pixel

Dependencies.

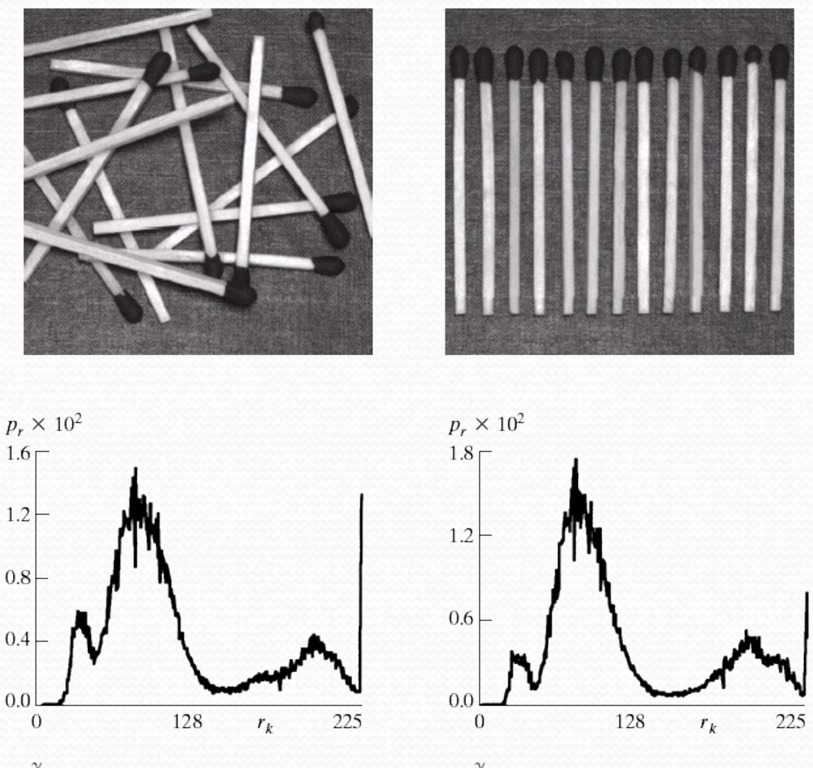
Spatial Redundancy

Each pixel can be estimated

Geometric Redundancy

From its neighbors

Inter-frame Redundancy



a b
c d
e f

FIGURE 8.2 Two images and their gray-level histograms and normalized autocorrelation coefficients along one line.

Psycho-visual Redundancy

Elimination of psych-visual redundant data results in a loss of quantitative information ,it is commonly referred as *quantization.*

a b c

FIGURE 8.4
(a) Original image.
(b) Uniform quantization to 16 levels. (c) IGS quantization to 16 levels.

Improved Gray-Scale

Psycho-visual Redundancy

IGS Quantization

Pixel	Gray Level	Sum	IGS Code
$i - 1$	N/A	0000 0000	N/A
i	0110 1100	0110 1100	0110
$i + 1$	1000 1011	1001 0111	1001
$i + 2$	1000 0111	1000 1110	1000
$i + 3$	1111 0100	1111 0100	1111

TABLE 8.2
IGS quantization procedure.

Fidelity Criteria

The general classes of criteria :

1. Objective fidelity criteria
2. Subjective fidelity criteria

Fidelity Criteria

Objective fidelity:

Level of information loss can be expressed as a function of the original and the compressed and subsequently decompressed image.

Root-mean-square error

$$e_{rms} = \left[\frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} [\hat{f}(x,y) - f(x,y)]^2 \right]^{1/2}$$

Mean-square signal-to-noise ratio

$$SNR_{ms} = \frac{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \hat{f}(x,y)^2}{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} [\hat{f}(x,y) - f(x,y)]^2}$$

Fidelity Criteria

a b c

FIGURE 8.4
(a) Original image.
(b) Uniform quantization to 16 levels. (c) IGS quantization to 16 levels.

$$e_{rms} = 6.93 \qquad e_{rms} = 6.78$$

$$SNR_{rm} = 10.25 \qquad SNR_{rm} = 10.39$$

Fidelity Criteria

Subjective fidelity (Viewed by Human):

- By absolute rating
- By means of side-by-side comparison of $f(x,y)$ and $\hat{f}(x,y)$

TABLE 8.3
Rating scale of the Television Allocations Study Organization. (Frendendall and Behrend.)

Value	Rating	Description
1	Excellent	An image of extremely high quality, as good as you could desire.
2	Fine	An image of high quality, providing enjoyable viewing. Interference is not objectionable.
3	Passable	An image of acceptable quality. Interference is not objectionable.
4	Marginal	An image of poor quality; you wish you could improve it. Interference is somewhat objectionable.
5	Inferior	A very poor image, but you could watch it. Objectionable interference is definitely present.
6	Unusable	An image so bad that you could not watch it.

Image Compression Model

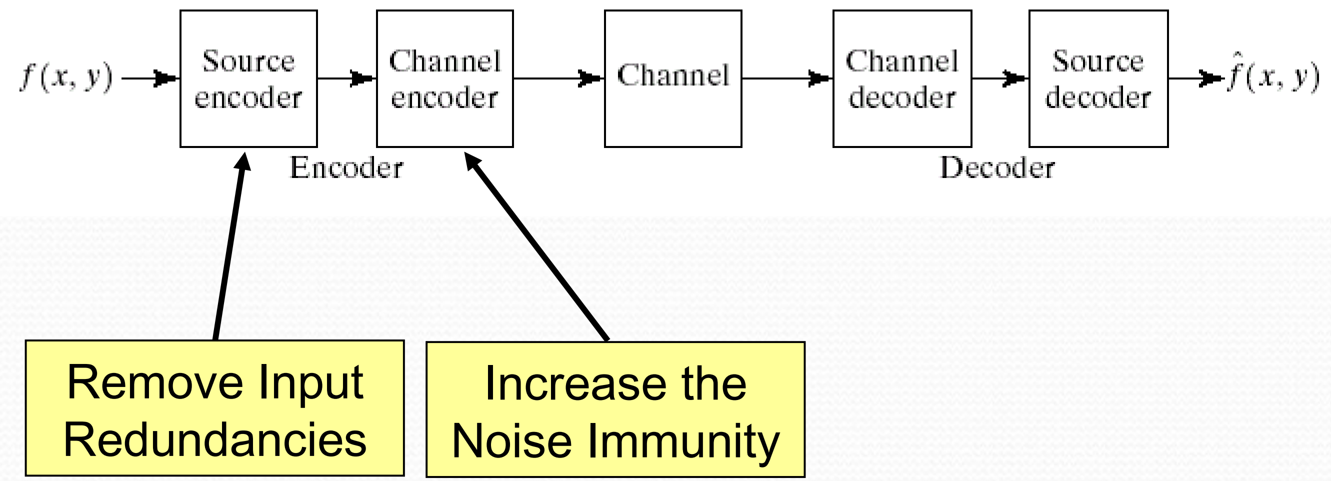


FIGURE 8.5 A general compression system model.

- The source encoder is responsible for removing redundancy (coding, inter-pixel, psycho-visual)

- The channel encoder ensures robustness against channel noise.

Classification

- Lossless compression
  - lossless compression for legal and medical documents, computer programs
  - exploit only code and inter-pixel redundancy
- Lossy compression
  - digital image and video where some errors or loss can be tolerated
  - exploit both code and inter-pixel redundancy and sycho-visual perception properties

Error-Free Compression

Applications:

- Archive of medical or business documents
- Satellite imaging
- Digital radiography

They provide: Compression ratio of 2 to 10.

Error-Free Compression

Variable-length Coding

Huffman coding

✓ The most popular technique for removing coding redundancy is due to Huffman (1952)

✓ Huffman Coding yields the smallest number of code symbols per source symbol

✓ The resulting code is *optimal*

Error-Free Compression

Variable-length Coding

Huffman coding (optimal code)

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				

FIGURE 8.11 Huffman source reductions.

Error-Free Compression

Variable-length Coding

Huffman coding

FIGURE 8.12 Huffman code assignment procedure.

Original source			Source reduction							
Sym.	Prob.	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								

$$L_{avg} = (0.4)(1) + (0.3)(2) + (0.1)(3) + (0.1)(4) + (0.06)(5) + (0.04)(5)$$

$$= 2.2\, bits / symbol$$

$$entropy = 2.14\, bits / symbol$$

LZW Coding

- ✓ Error Free Compression Technique.
- ✓ Remove Inter-pixel redundancy.
- ✓ Requires no priori knowledge of probability distribution of pixels.
- ✓ Assigns fixed length code words to variable length sequences.
- ✓ Patented Algorithm US 4,558,302.

LZW Coding

Coding Technique

- A codebook or a dictionary has to be constructed
- For an 8-bit monochrome image, the first 256 entries are assigned to the gray levels 0,1,2,..,255.
- As the encoder examines image pixels, gray level sequences that are not in the dictionary are assigned to a new entry.

LZW Coding

Example

Consider the following 4 x 4 8 bit image

39	39	126	126
39	39	126	126
39	39	126	126
39	39	126	126

Dictionary Location	Entry
0	0
1	1
.	.
255	255
256	-

Initial Dictionary

LZW Coding

39	39	126	126
39	39	126	126
39	39	126	126
39	39	126	126

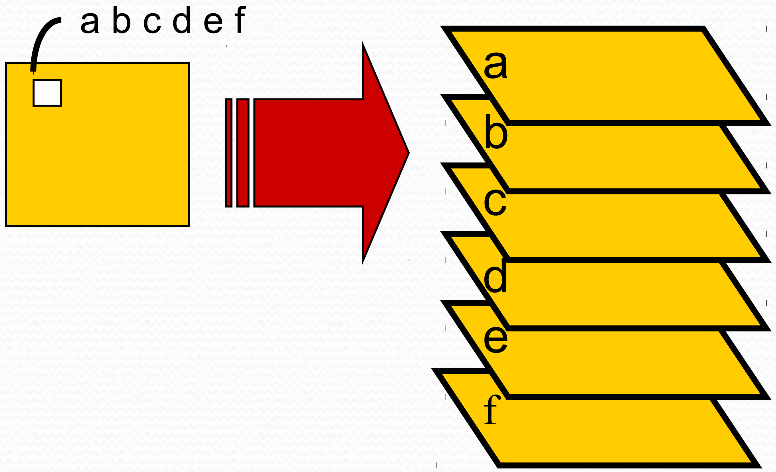
Dictionary Location	Entry
0	0
1	1
.	.
255	255
256	39-39 -

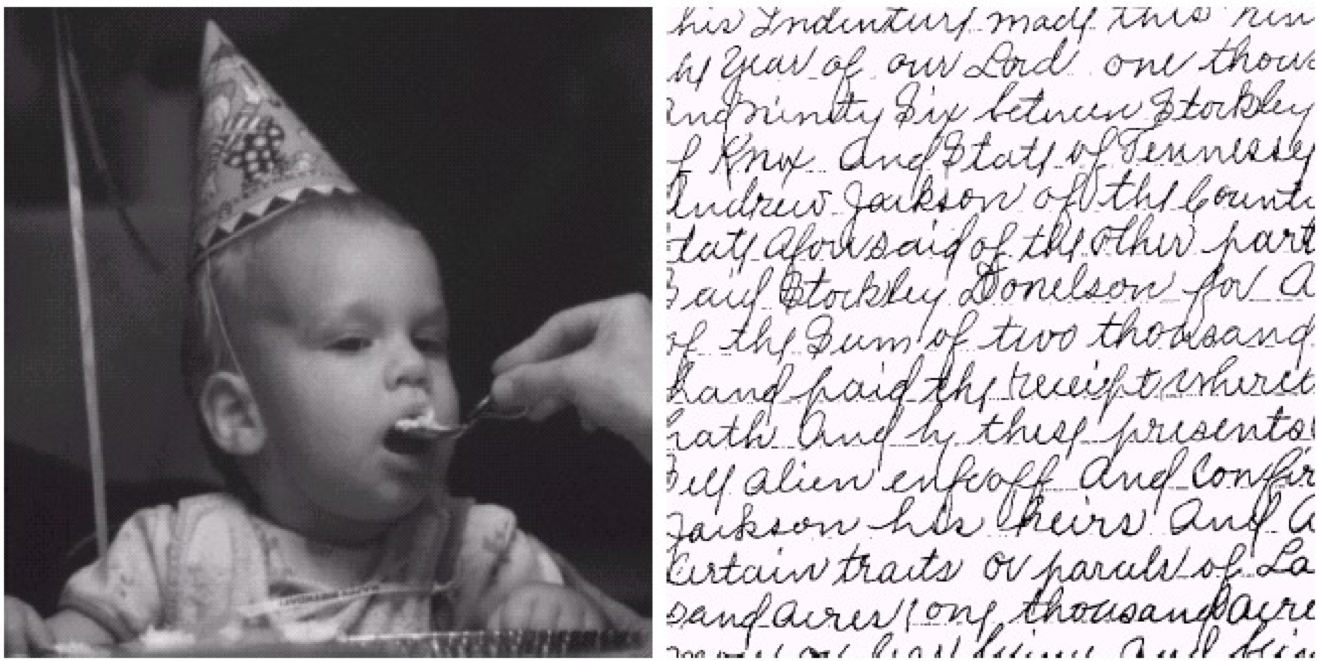
- Is 39 in the dictionary……..Yes
- What about 39-39………….No
- Then add 39-39 in entry 256
- And output the last recognized symbol…39

Error-Free Compression

Bit-plane coding

Bit-plane coding is based on decomposing a multilevel image into a series of binary images and compressing each binary image .





a b

FIGURE 8.14 A 1024 × 1024 (a) 8-bit monochrome image and (b) binary image.

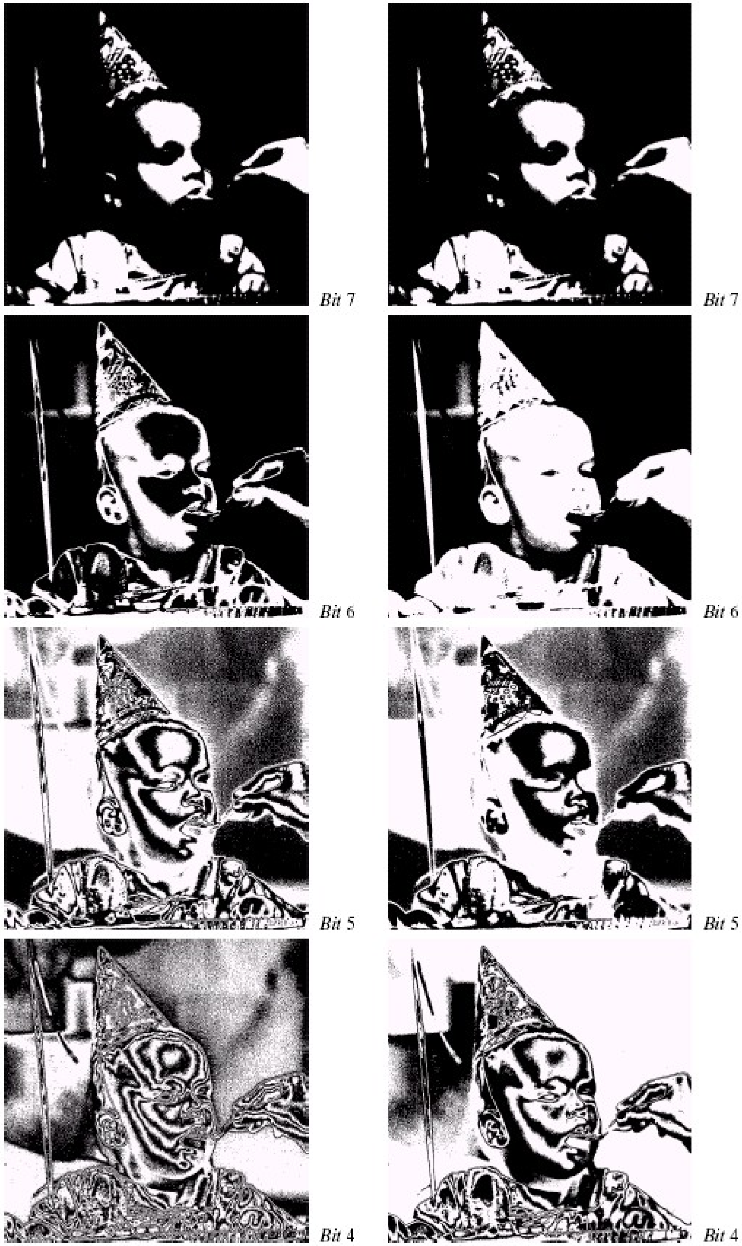
Error-Free Compression

Bit-plane coding

Bit-plane decomposition

FIGURE 8.15 The four most significant binary (left column) and Gray-coded (right column) bit planes of the image in Fig. 8.14(a).

Binary Bit-planes Gray Bit-planes



$$m-bit\ gray\ scale:\quad a_{m-1}2^{m-1}+a_{m-2}2^{m-2}+\cdots+a_0 2^0$$

$$Gray\ code: g_{m-1}g_{m-2}\cdots g_1 g_0$$

$$g_l = a_l \oplus a_{l+1} \qquad 0 \le l \le m-2$$

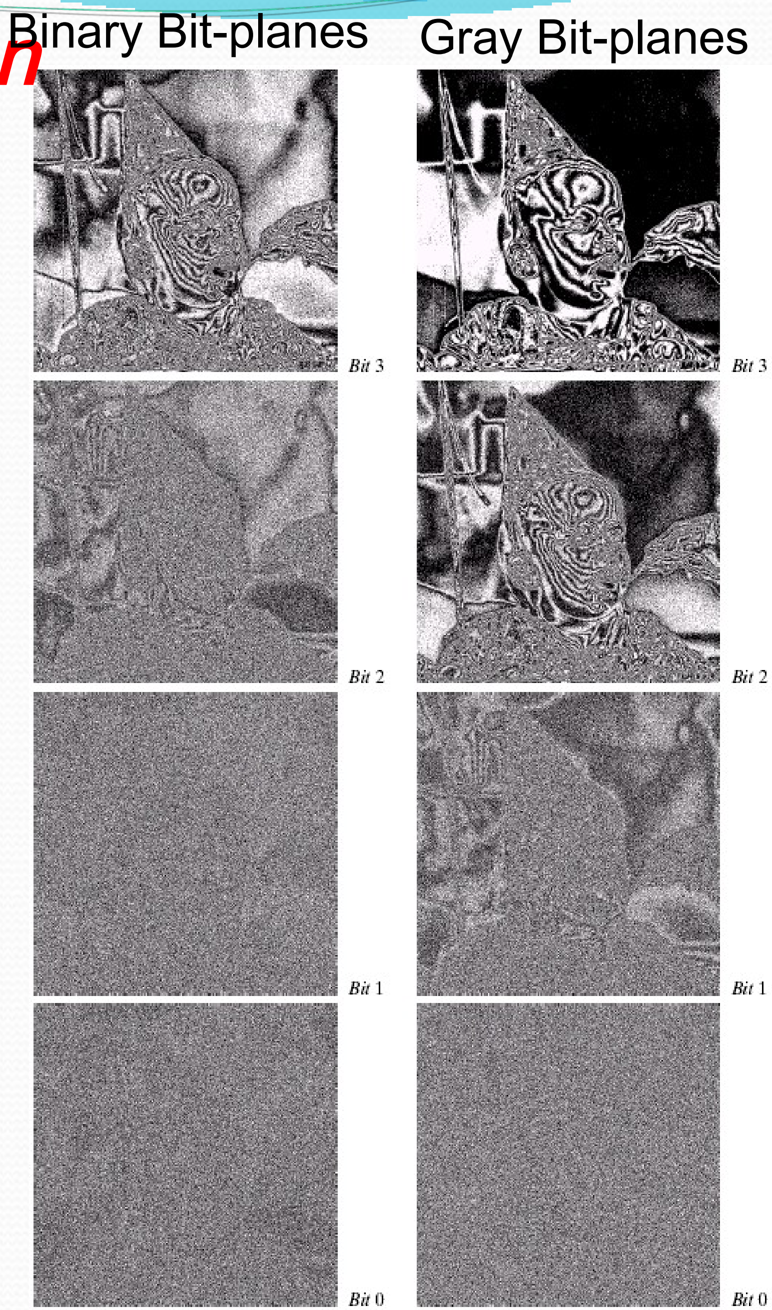
$$g_{m-1} = a_{m-1}$$

Error-Free Compression

Bit-plane coding

Bit-plane decomposition

FIGURE 8.16 The four least significant binary (left column) and Gray-coded (right column) bit planes of the image in Fig. 8.14(a).



Error-Free Compression

Bit-plane coding

- Constant area Coding
- One-dimensional run-length coding

$$H_{RL} = \frac{H_0 + H_1}{L_0 + L_1}$$

Average values of black and white run lengths

- Two-dimensional RLC

➢Relative Address Coding (RAC) is based on tracking the binary transitions.

Error-Free Compression
Loss-less Predictive Coding

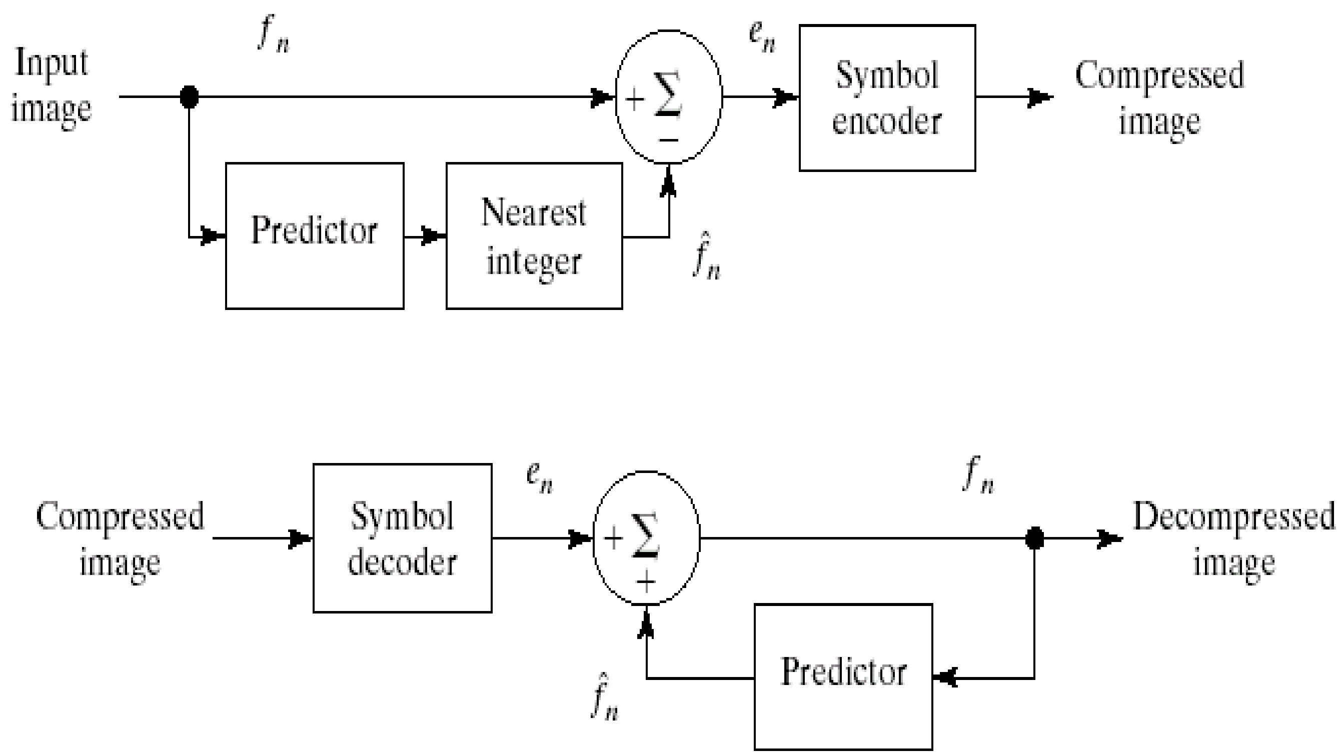


FIGURE 8.19 A lossless predictive coding model: (a) encoder; (b) decoder.

Error-Free Compression

Loss-less Predictive Coding

In most cases, the prediction is formed by a linear combination of *m* previous pixels. That is:

$$\hat{f}_n = round\left[\sum_{l=1}^{m} \alpha_l f_{n-l}\right]$$

1-D Linear Predictive coding:

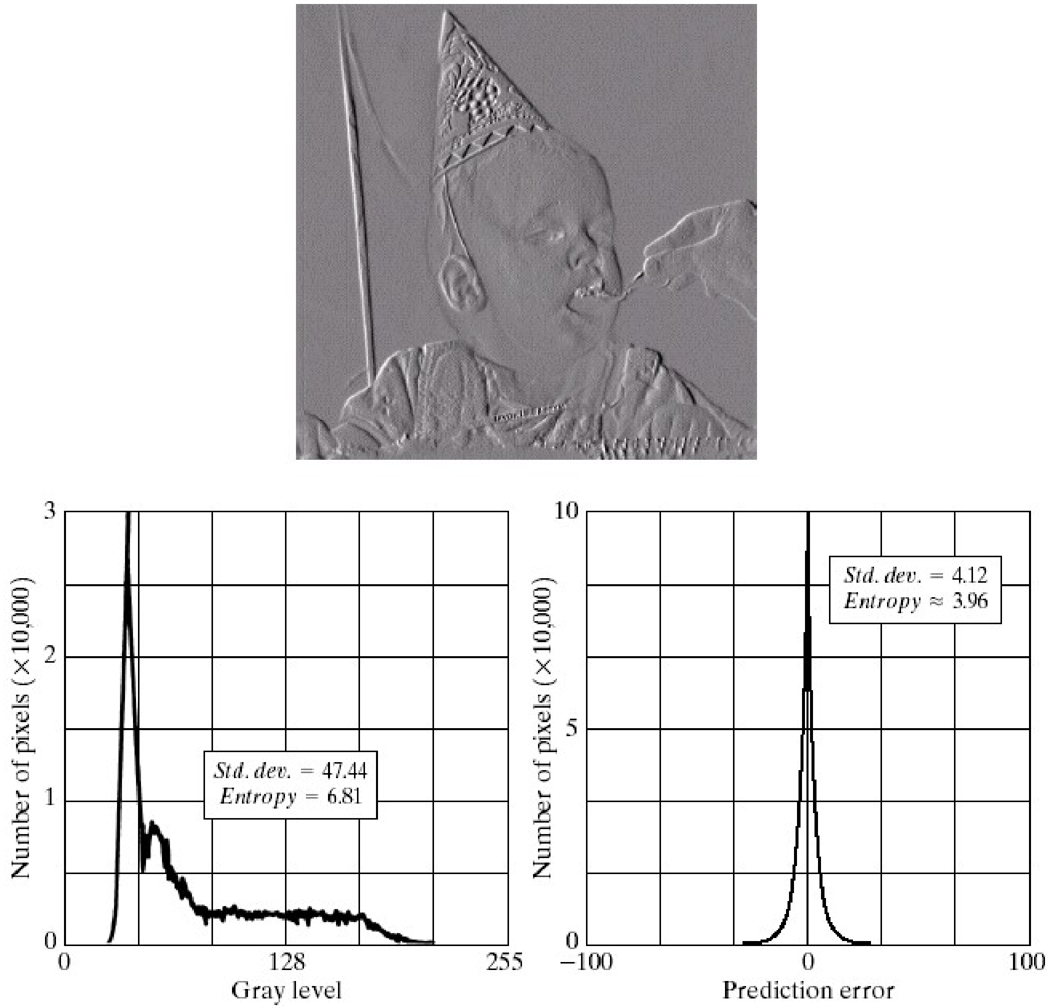
$$\hat{f}_n(x,y) = round\left[\sum_{i=1}^{m} \alpha_i f(x, y-i)\right]$$

m is the order of linear predictor

Error-Free Compression

Loss-less Predictive Coding

$$\hat{f}(x,y) = round\left[\alpha f(x,y-1)\right]$$ **First-order linear predictor**



a
b c

FIGURE 8.20 (a) The prediction error image resulting from Eq. (8.4-9). (b) Gray-level histogram of the original image. (c) Histogram of the prediction error.

Lossy Compression

Lossy encoding is based on the concept of compromising the accuracy of the reconstructed image in exchange for increased compression.

Lossy encoding techniques are capable of reproducing recognizable mono-chrome images from data that have been compressed by more than 100:1 and images that are virtually indistinguishable from the original at 10:1 to 50:1 .

Lossy Compression:

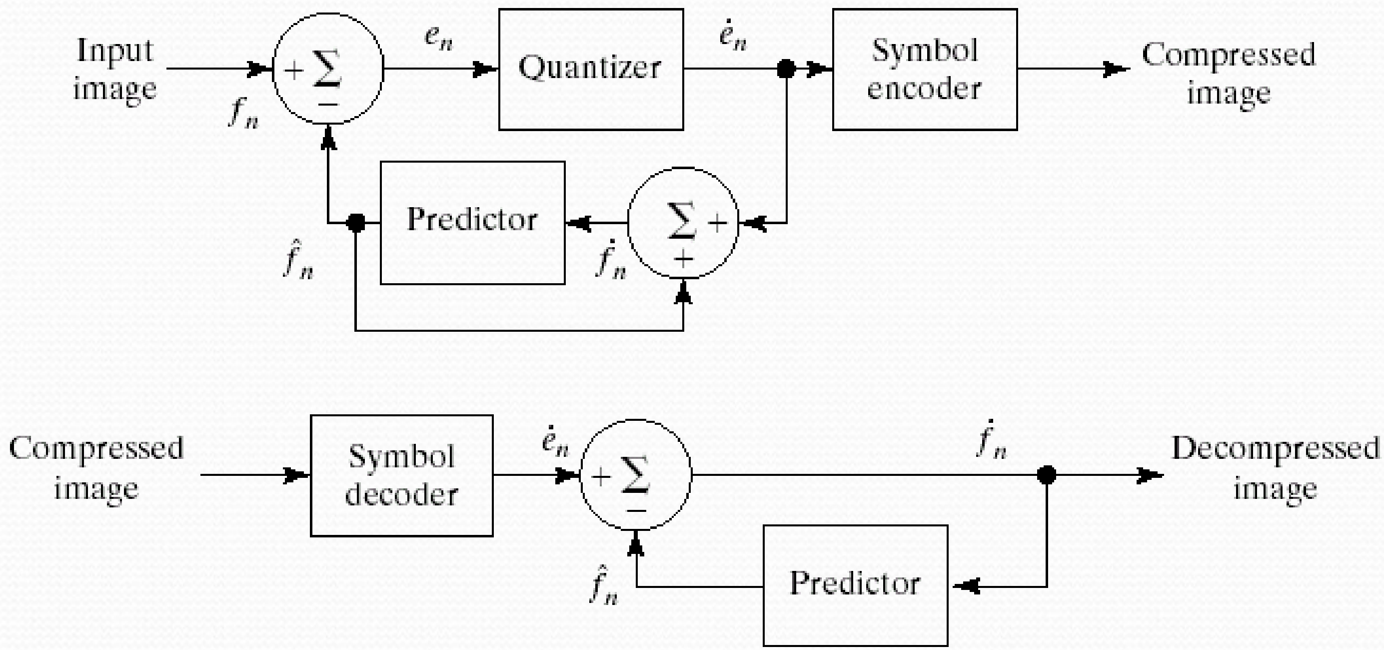
1. Spatial domain methods
2. Transform coding

Lossy Compression
Lossy Predictive Coding

- **Predictive Coding :** transmit the difference between estimate of future sample & the sample itself.

  - Delta modulation
  - DPCM
  - Adaptive predictive coding
  - Differential frame coding

Lossy Compression
Lossy Predictive Coding



a
b

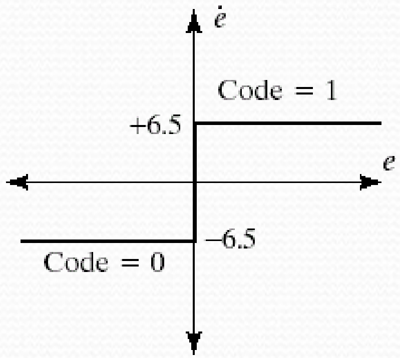
FIGURE 8.21 A lossy predictive coding model: (a) encoder and (b) decoder.

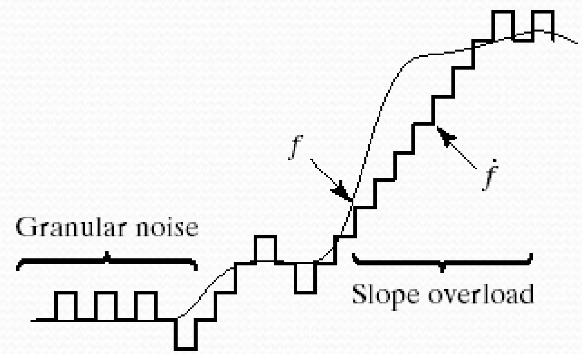
Lossy Compression

Lossy Predictive Coding – Delta Modulation (DM)

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

$$\dot{e}_n = \begin{cases} +\xi & \text{for } e_n > 0 \\ -\zeta & \text{otherwise} \end{cases}$$





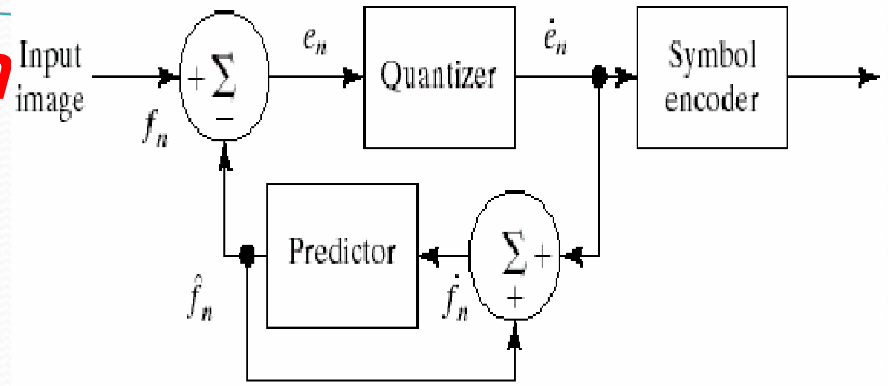
Input		Encoder				Decoder		Error
n	f	$\hat{f}$	e	$\dot{e}$	$\dot{f}$	$\hat{f}$	$\dot{f}$	$[f - \dot{f}]$
0	14	—	—	—	14.0	—	14.0	0.0
1	15	14.0	1.0	6.5	20.5	14.0	20.5	–5.5
2	14	20.5	–6.5	–6.5	14.0	20.5	14.0	0.0
3	15	14.0	1.0	6.5	20.5	14.0	20.5	–5.5
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
14	29	20.5	8.5	6.5	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
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.

a b
c

FIGURE 8.22 An example of delta modulation.

Lossy Compression

Optimal Prediction



$$E\{e_n^2\} = E\{[f_n - \hat{f}_n]^2\}$$

$$\dot{f}_n = \dot{e}_n + \hat{f}_n \approx e_n + \hat{f}_n = f_n$$

$$\hat{f}_n = \sum_{i=1}^{m} \alpha_i f_{n-i}$$

Differential Pulse Code Modulation (DPCM)

$$E\{e_n^2\} = E\left\{\left[f_n - \sum_{i=1}^{m} \alpha_i f_{n-i}\right]^2\right\}$$

$$\sum_{i=1}^{m} \alpha_i \leq 1$$

Lossy Compression

Optimal Prediction

Prediction Error

$$\hat{f}(x,y) = 0.97 f(x,y-1)$$ **Pred. #1**

$$\hat{f}(x,y) = 0.5 f(x,y-1) + 0.5 f(x-1,y)$$ **Pred. #2**

$$\hat{f}(x,y) = 0.75 f(x,y-1) + 0.75 f(x-1,y) - 0.5 f(x-1,y-1)$$ **Pred. #3**

$$\hat{f}(x,y) = \begin{cases} 0.97 f(x,y-1) & \text{if } \Delta h \le \Delta v \\ 0.97 f(x-1,y) & \text{otherwise} \end{cases}$$ **Pred. #4**

$$\Delta h = \left| f(x-1,y) - f(x-1,y-1) \right| \text{ and } \Delta v = \left| f(x,y-1) - f(x-1,y-1) \right|$$

Lossy Compression
Optimal Prediction

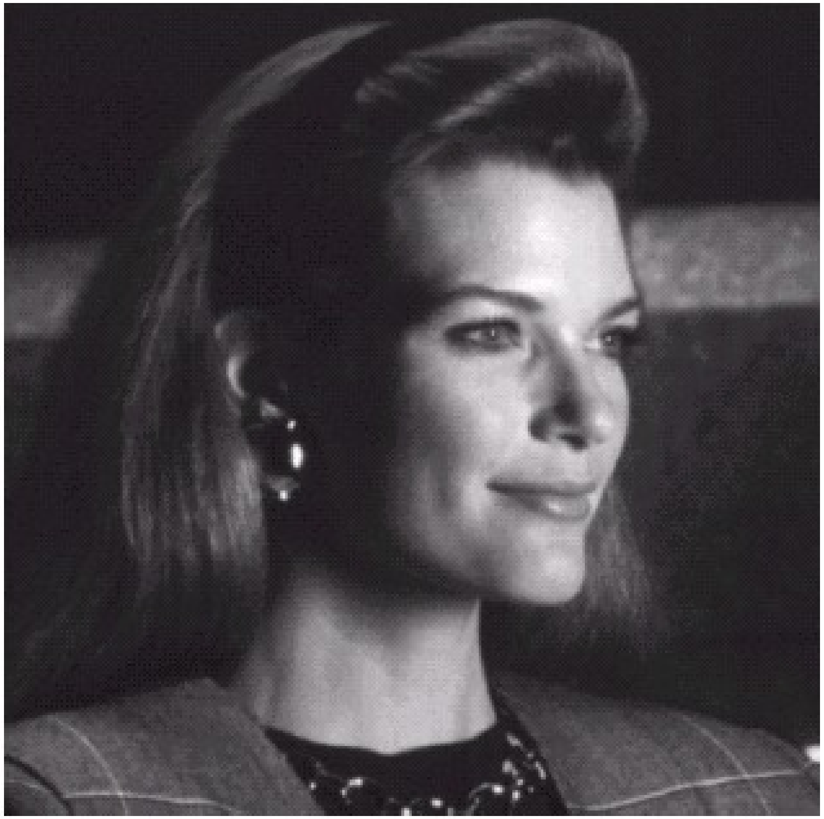


FIGURE 8.23 A 512×512 8-bit monochrome image.

Lossy Compression

Prediction Error for different predictors

a b
c d

FIGURE 8.24 A comparison of four linear prediction techniques.

Pred. #1

Pred. #2

Pred. #3

Pred. #4

Lossy Compression

Optimal Quantization

$$t = q(s) \qquad (q \text{ is an odd function})$$

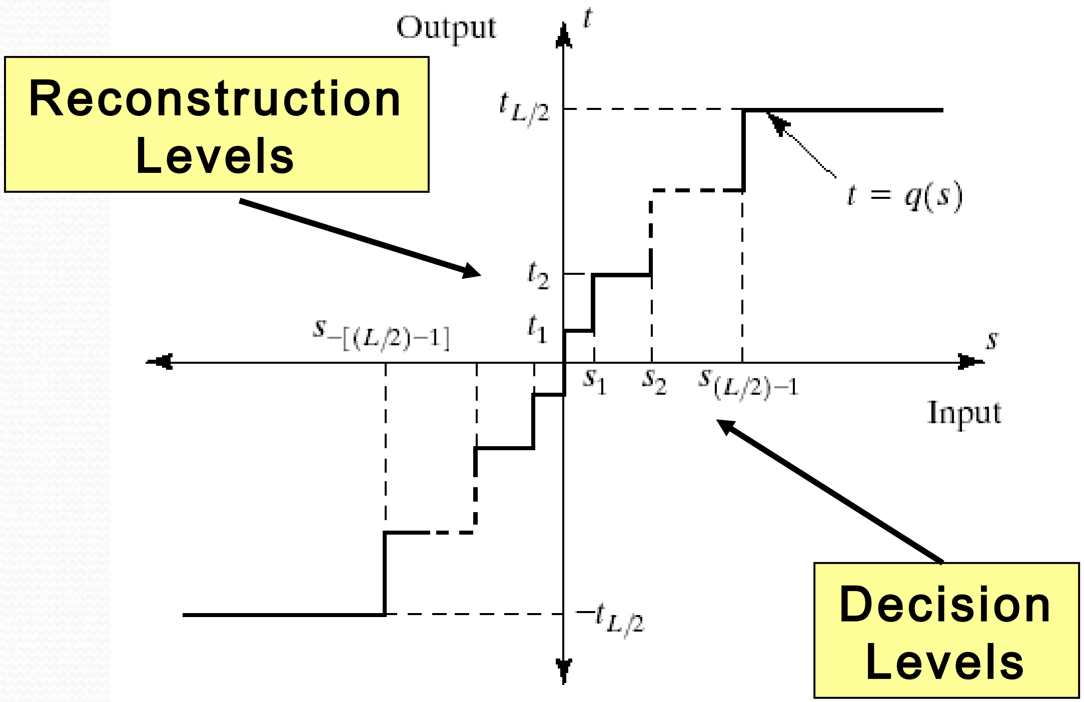


FIGURE 8.25 A typical quantization function.

Lossy Compression

Optimal Quantization

$$t = q(s) \qquad (q \text{ is an odd function})$$

Minimization of the mean-square quantization error

$$\int_{s_{i-1}}^{s_i} (s - t_i)\, p(s)\, ds \qquad i = 1, 2, \cdots, L/2$$

$$s_i = \begin{cases} 0 & i = 0 \\ \dfrac{t_i + t_{i+1}}{2} & i = 1, 2, \cdots, \dfrac{L}{2} - 1 \\ \infty & i = \dfrac{L}{2} \end{cases}$$

$$s_{-i} = -s_i \quad t_{-i} = -t_i$$

Additional constraint for optimum uniform quantizer:

$$t_i - t_{i-1} = s_i - s_{i-1} = \theta$$

Lossy Compression
Optimal Quantization

Unit variance Laplacian probability density function

TABLE 8.10
Lloyd-Max quantizers for a Laplacian probability density function of unit variance.

Levels	2		4		8	
i	s_i	t_i	s_i	t_i	s_i	t_i
1	∞	0.707	1.102	0.395	0.504	0.222
2			∞	1.810	1.181	0.785
3					2.285	1.576
4					∞	2.994
θ	1.414		1.087		0.731	

As this table constructed for a unit variance distribution, the reconstruction and decision levels for the case of $\sigma \neq 1$ are obtained by multiplying the tabulated values by the standard deviation 0of the probability density function

Lossy Compression
DPCM RMSE

The best of four possible quantizers is selected for each block of 16 pixels.

Scaling factors: 0.5, 1.0, 1.75 and 2.5

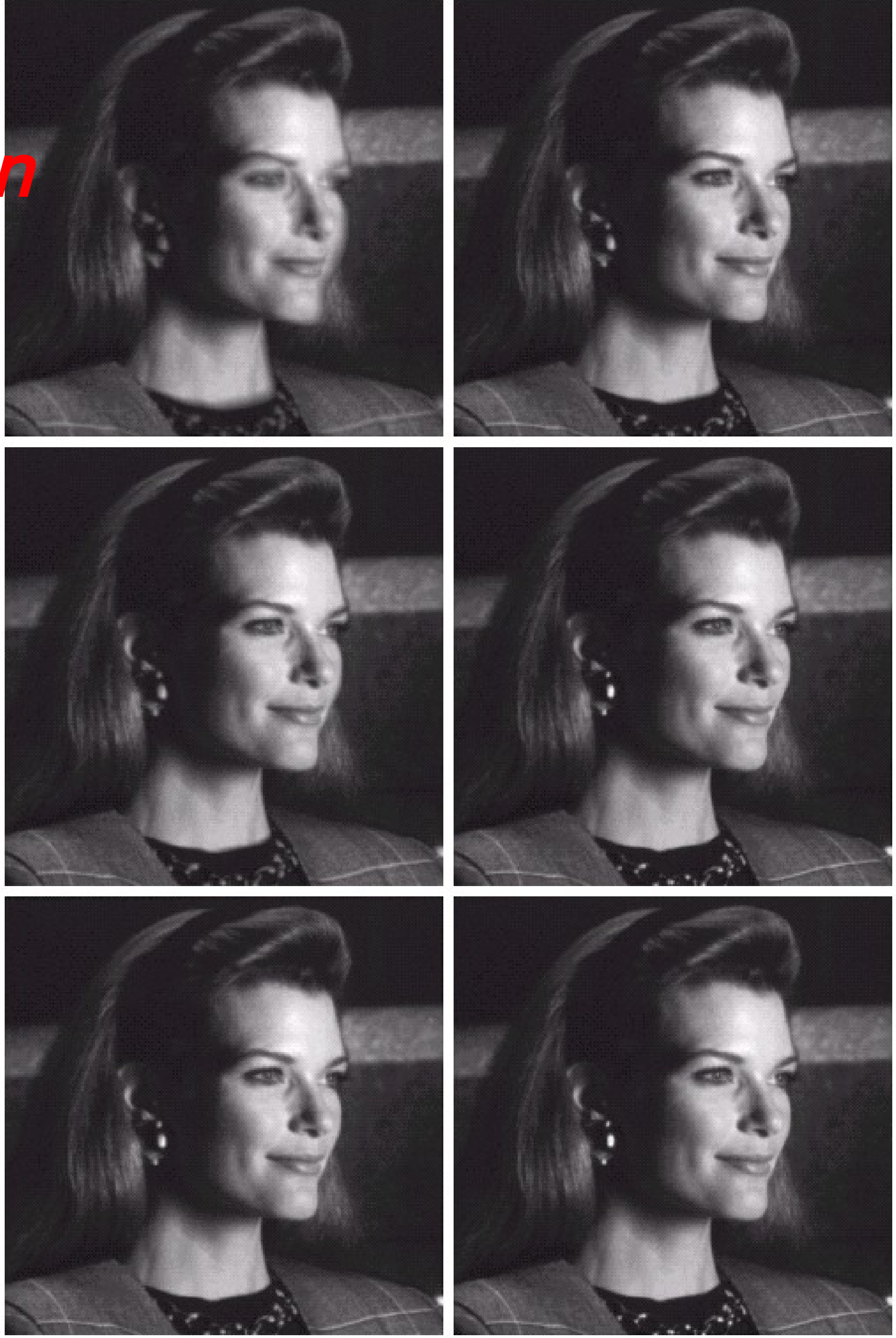
	Lloyd-Max Quantizer			Adaptive Quantizer		
Predictor	**2-level**	**4-level**	**8-level**	**2-level**	**4-level**	**8-level**
Eq. (8.5-16)	30.88	6.86	4.08	7.49	3.22	1.55
Eq. (8.5-17)	14.59	6.94	4.09	7.53	2.49	1.12
Eq. (8.5-18)	9.90	4.30	2.31	4.61	1.70	0.76
Eq. (8.5-19)	38.18	9.25	3.36	11.46	2.56	1.14
Compression	8.00:1	4.00:1	2.70:1	7.11:1	3.77:1	2.56:1

TABLE 8.11 Lossy DPCM root-mean-square error summary.

Lossy Compression

DPCM result images

2-level Lloyd-Max quantizer 1.0 bits/pixel	2-level adaptive quantizer 1.125 bits/pixel
4-level Lloyd-Max quantizer 2.0 bits/pixel	4-level adaptive quantizer 2.125 bits/pixel
8-level Lloyd-Max quantizer 3.0 bits/pixel	8-leveladaptive quantizer 3.125 bits/pixel



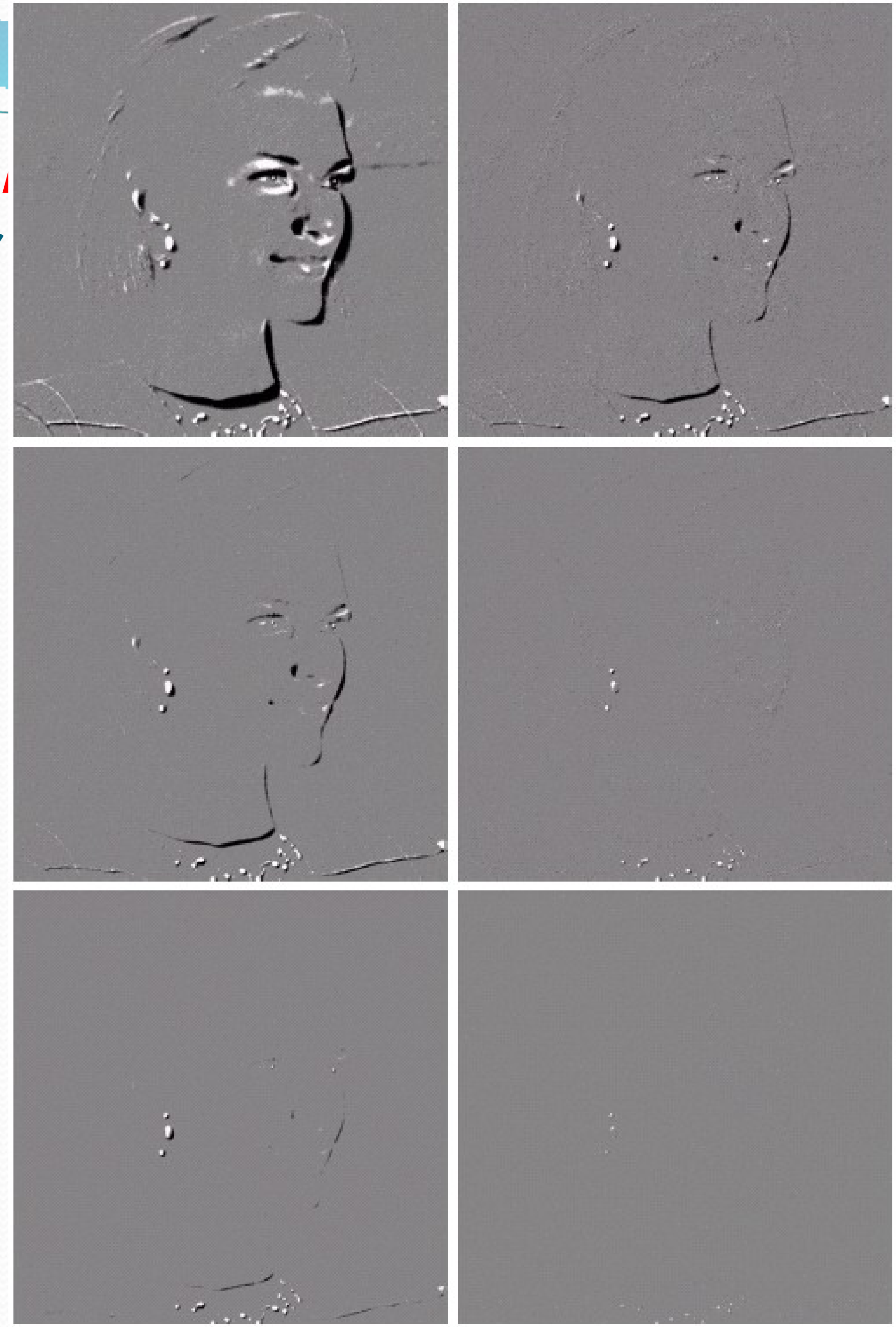
a	b
c	d
e	f

FIGURE 8.26 DPCM result images: (a) 1.0; (b) 1.125; (c) 2.0; (d) 2.125; (e) 3.0; (f) 3.125 bits/pixel.

Lossy Compressio

DPCM Prediction Error

2-level Lloyd-Max quantizer 1.0 bits/pixel	2-level adaptive quantizer 1.125 bits/pixel
4-level Lloyd-Max quantizer 2.0 bits/pixel	4-level adaptive quantizer 2.125 bits/pixel
8-level Lloyd-Max quantizer 3.0 bits/pixel	8-leveladaptive quantizer 3.125 bits/pixel



a	b
c	d
e	f

FIGURE 8.26 DPCM result images: (a) 1.0; (b) 1.125; (c) 2.0; (d) 2.125; (e) 3.0; (f) 3.125 bits/pixel.

Lossy Compression
Transform Coding

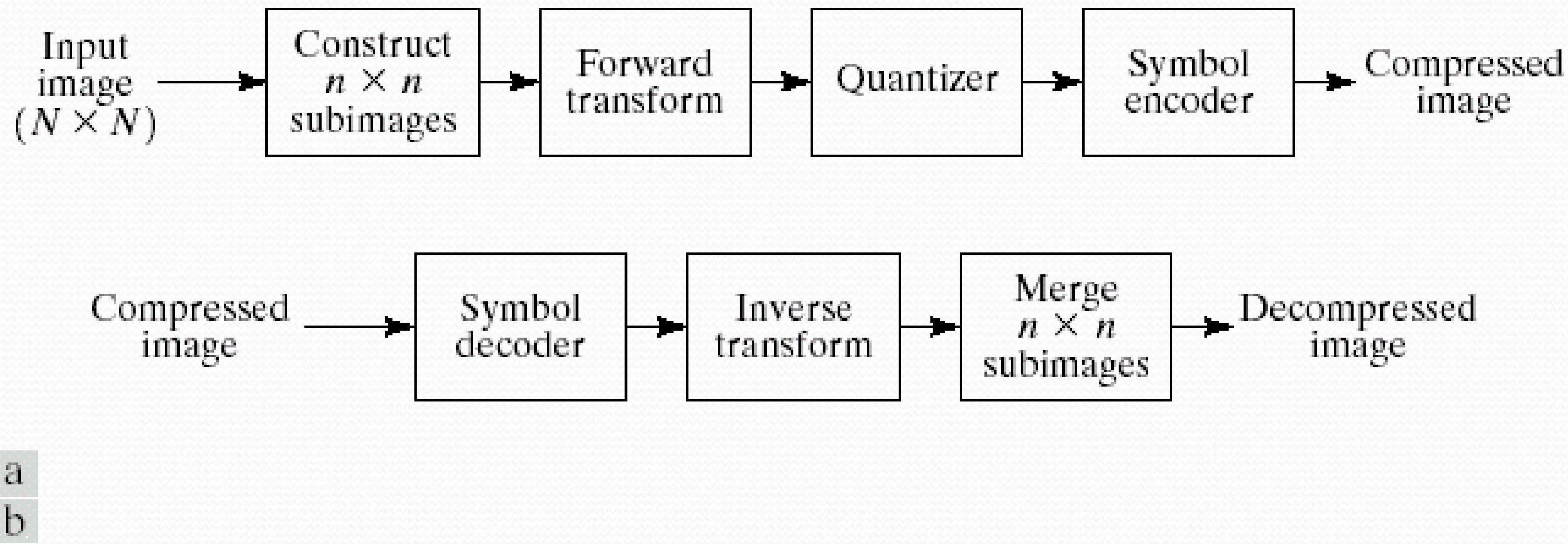


FIGURE 8.28 A transform coding system: (a) encoder; (b) decoder.

The goal of the transformation process is to decorrelate the pixels of each sub-image, or to pack as much information as possible into the smallest number of transform coefficients

Lossy Compression

Transform Coding

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

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

Forward kernel is Separable if:

$$g(x,y,u,v)=g_1(x,u).g_2(y,v)$$

Forward kernel is Symmetric if:

$$g_1=g_2 \Rightarrow g(x,y,u,v)=g_1(x,u).g_1(y,v)$$

Lossy Compression

Transform Coding

Discrete Fourier Transform (DFT):

$$g(x,y,u,v)=\frac{1}{N}e^{-j2\pi(ux+vy)/N}$$

$$h(x,y,u,v)=e^{j2\pi(ux+vy)/N}$$

Walsh-Hadamard Transform (WHT):

$$g(x,y,u,v)=h(x,y,u,v)=\frac{1}{N}(-1)^{\sum_{i=0}^{m-1}[b_i(x)p_i(u)+b_i(y)p_i(v)]} \qquad (N=2^m)$$

$b_k(z)$ **is the *k*th bit (from right to left) in the binary representation of z.**

Lossy Compression
Transform Coding

$$p_0(u) = b_{m-1}(u)$$
$$p_1(u) = b_{m-1}(u) + b_{m-2}(u)$$
$$p_2(u) = b_{m-2}(u) + b_{m-3}(u)$$
$$\vdots$$
$$p_{m-1}(u) = b_1(u) + b_0(u)$$

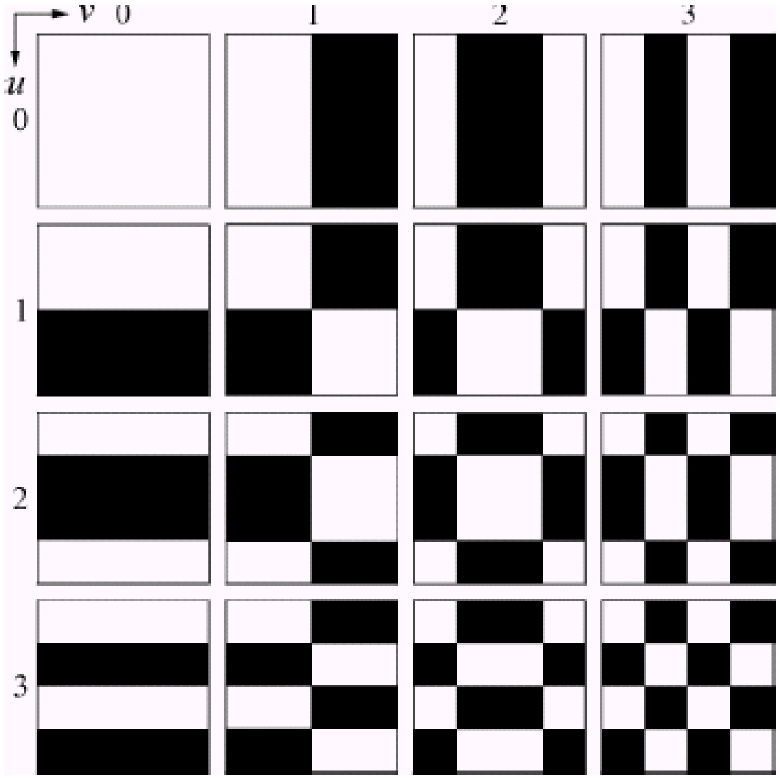


FIGURE 8.29 Walsh-Hadamard basis functions for $N = 4$. The origin of each block is at its top left.

Lossy Compression
Transform Coding

Discrete Cosin Transform (DCT):

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

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

$$where \qquad \alpha(u) = \begin{cases} \sqrt{\dfrac{1}{N}} & for\, u = 0 \\ \sqrt{\dfrac{2}{N}} & for\, u = 1,2,\cdots,N-1 \end{cases}$$

Lossy Compression

Transform Coding

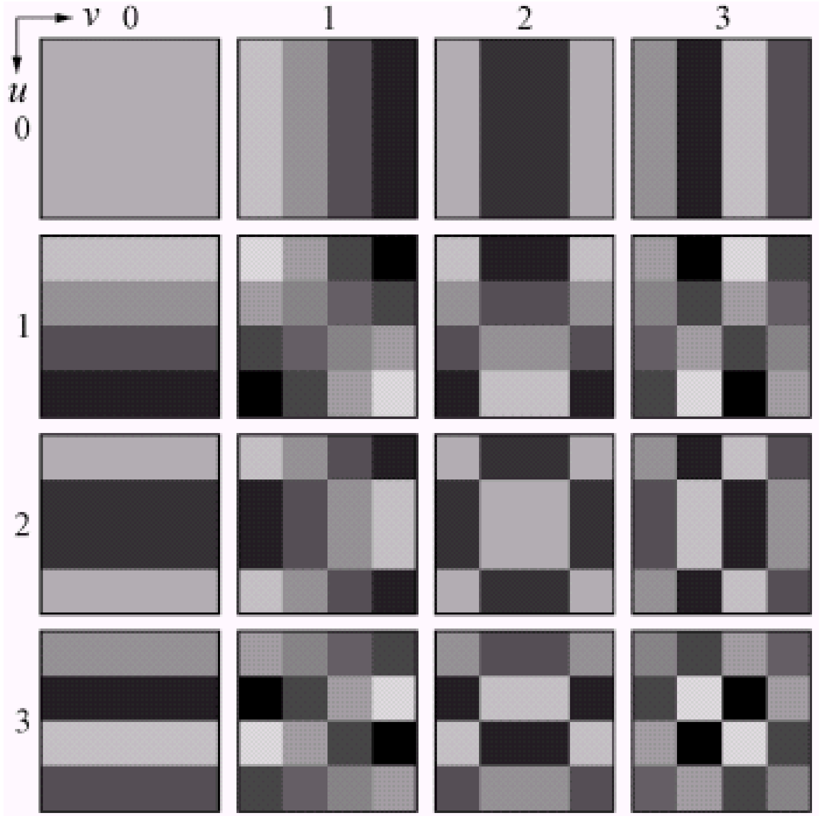
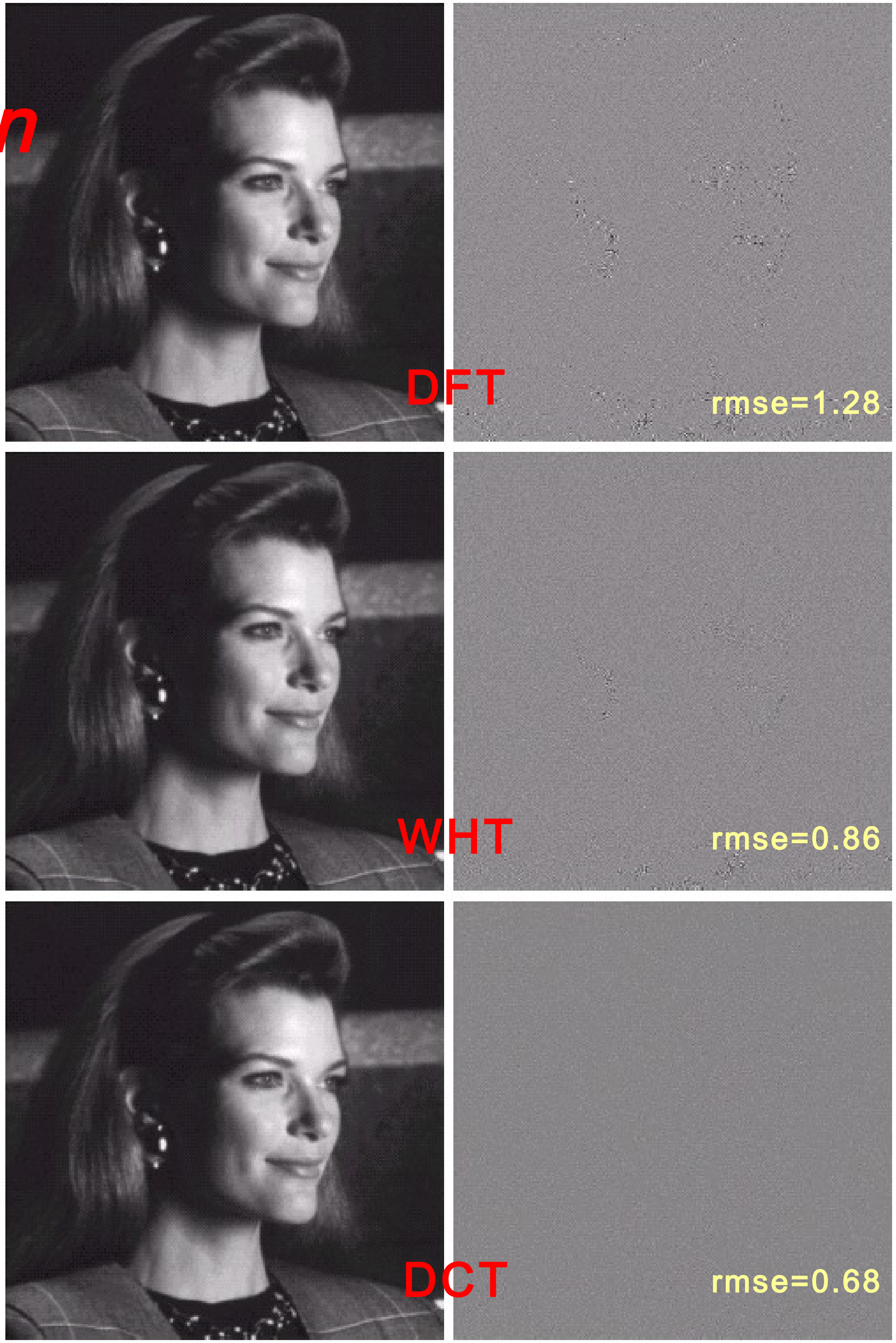


FIGURE 8.30 Discrete-cosine basis functions for $N = 4$. The origin of each block is at its top left.

Lossy Compression

Transform Coding

1. Dividing the image into sub-images of size 8x8
2. Representing each sub-image using one of the transforms
3. Truncating 50% of the resulting coefficients
4. Taking the inverse Transform of the truncated coefficients



a b
c d
e f

FIGURE 8.31 Approximations of Fig. 8.23 using the (a) Fourier, (c) Hadamard, and (e) cosine transforms, together with the corresponding scaled error images.

Lossy Compression
Transform Coding

- DCT Advantages:
  1. Implemented in a single integrated circuit (IC)
  2. Packing the most information into the fewest coefficients
  3. Minimizing the block-like appearance (blocking artif

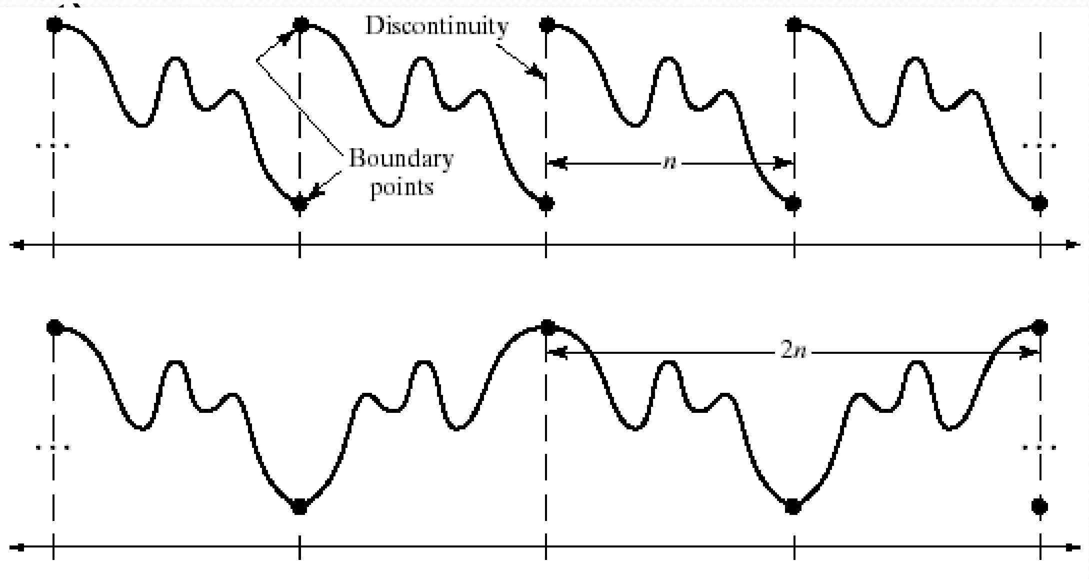


FIGURE 8.32 The periodicity implicit in the 1-D (a) DFT and (b) DCT.

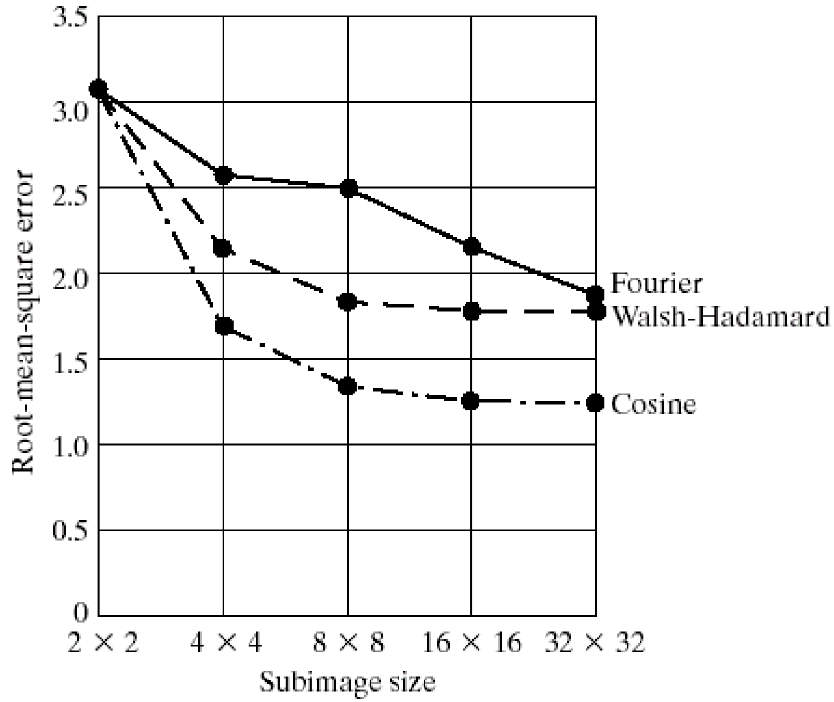
Lossy Compression

Transform Coding

Sub-image size selection

Truncating 75% of the resulting coefficients

FIGURE 8.33 Reconstruction error versus subimage size.



Lossy Compression

Transform Coding

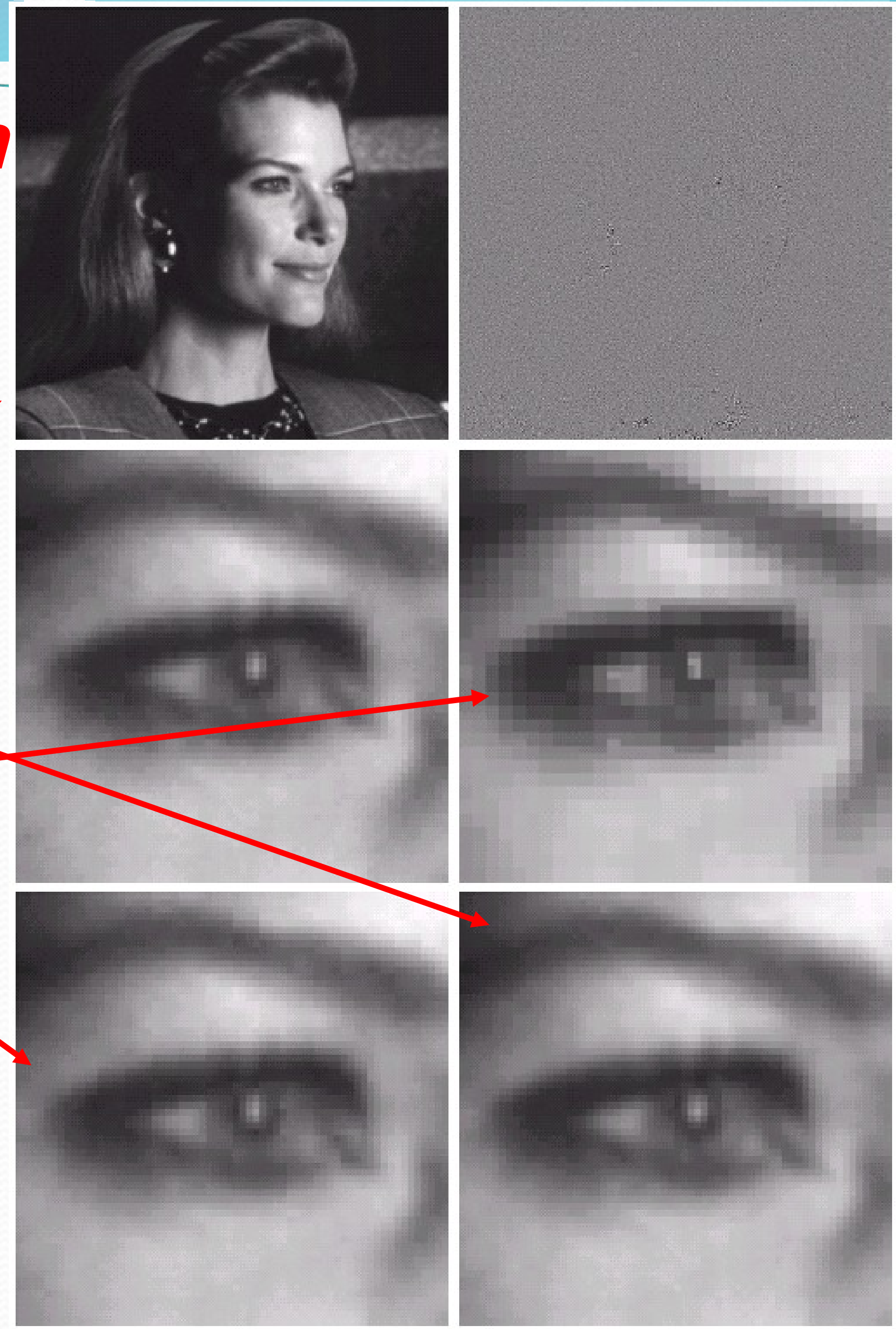
Truncating 75% of the resulting coefficients.

Sub-images size:

8x8

4x4

2x2



a b
c d
e f

FIGURE 8.34 Approximations of Fig. 8.23 using 25% of the DCT coefficients: (a) and (b) 8×8 subimage results; (c) zoomed original; (d) 2×2 result; (e) 4×4 result; and (f) 8×8 result.

Lossy Compression

Transform Coding

Bit allocation

87.5% of the DCT coeff. Of each 8x8 subimage.

Threshold coding (8 coef)

Zonal coding

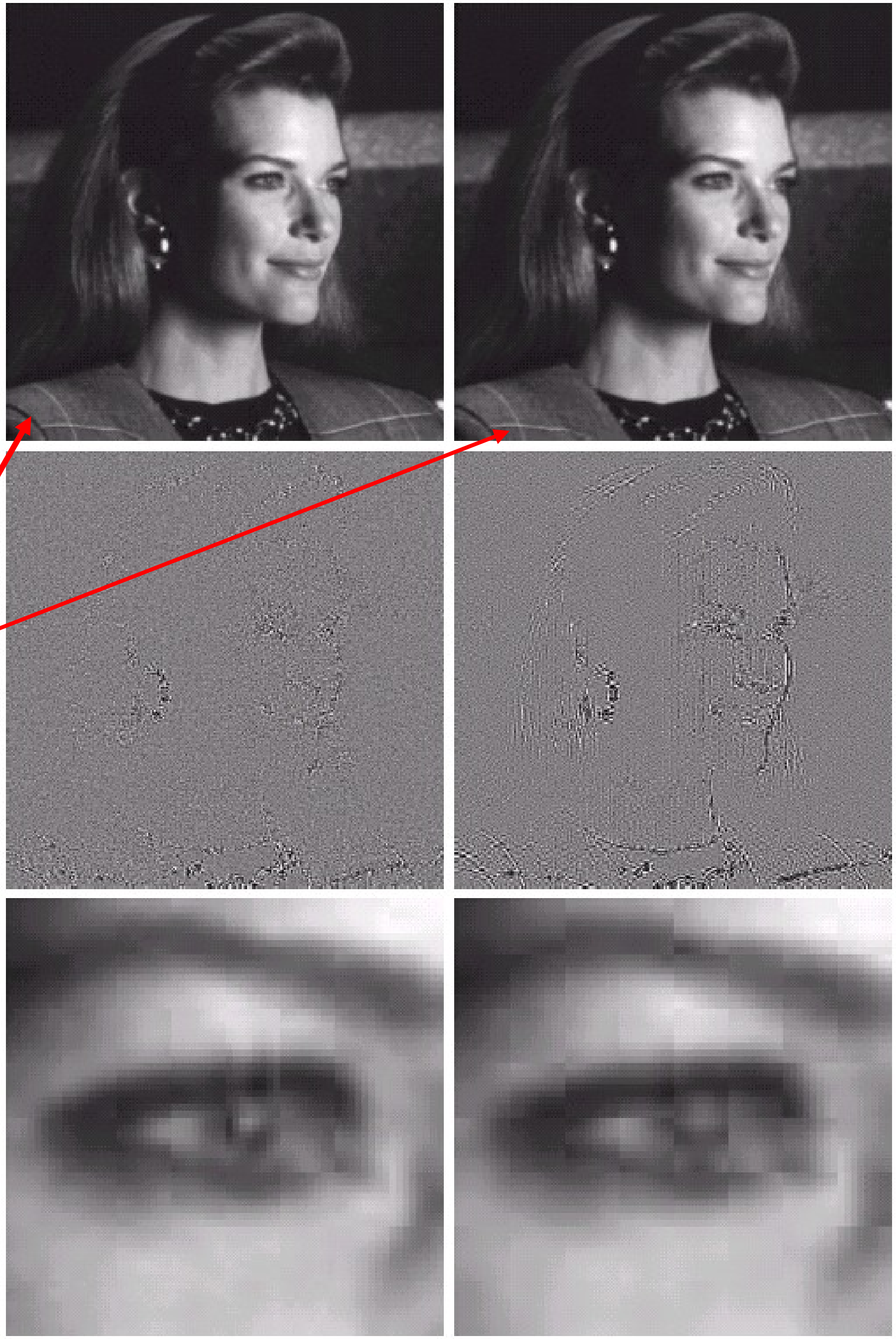


FIGURE 8.35 Approximations of Fig. 8.23 using 12.5% of the 8 × 8 DCT coefficients: (a), (c), and (e) threshold coding results; (b), (d), and (f) zonal coding results.

Lossy Compression
Transform Coding- Bit allocation

a	b
c	d

FIGURE 8.36 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.

(a)

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

(b)

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

(c)

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

(d)

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

Lossy Compression
Transform Coding- Bit allocation

- Zonal coding

1. Fixed number of bits / coefficient

   - Coefficients are normalized by their standard deviations and uniformly quantized

2. Fixed number of bits is distributed among the coefficients unequally.

   - A quantizer such as an optimal Lloyed-Max is designed for each coeff.:

     - DC coeff. Is modeled by Rayleigh density func.

     - The remaining coeff. Are modeled by Laplcian or

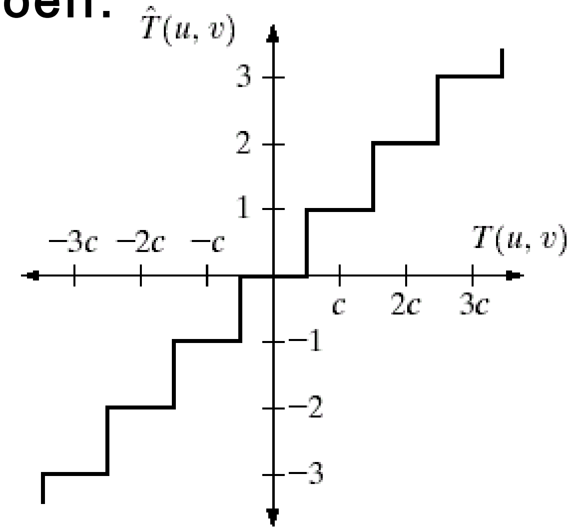
     Gaussian

Lossy Compression
Transform Coding- Bit allocation

- **Threshold coding**
  1. **Single global threshold**
  2. **Different threshold for each subimage (N-Largest coding)**
  3. **Threshold can be varied as a function of the location of each coeff.**

a b

FIGURE 8.37
(a) A threshold coding quantization curve [see Eq. (8.5-40)]. (b) A typical normalization matrix.



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

Lossy Compression
Transform Coding

Bit allocation

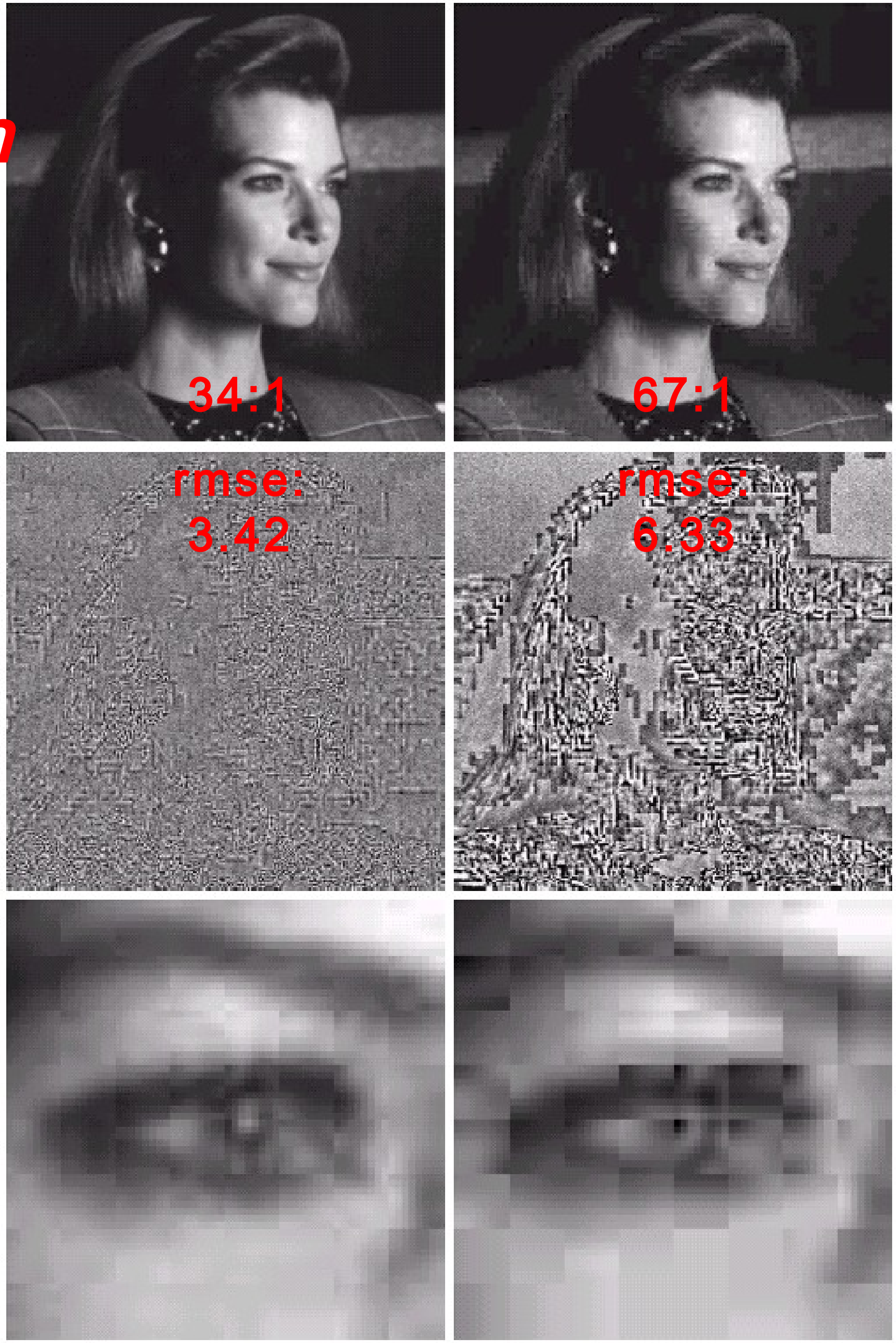


FIGURE 8.38 Left column: Approximations of Fig. 8.23 using the DCT and normalization array of Fig. 8.37(b). Right column: Similar results for 4**Z**.

Lossy Compression

Transform Coding

Wavelet Coding

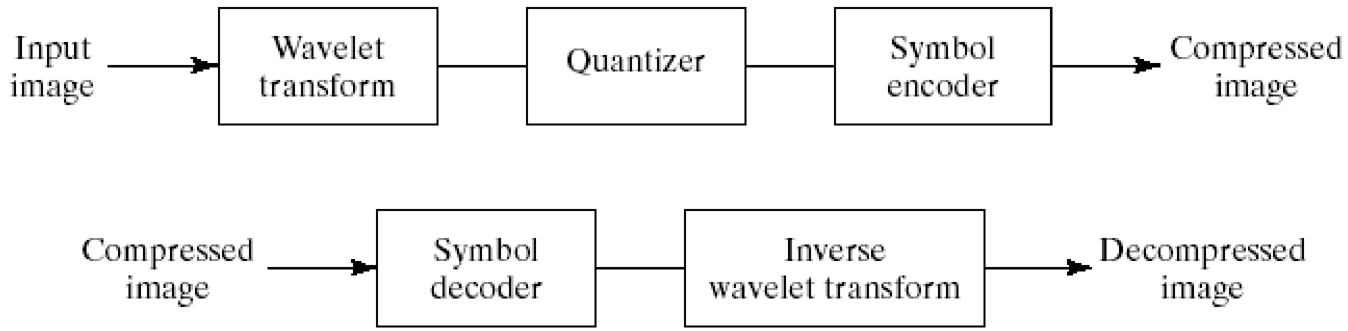


FIGURE 8.39 A wavelet coding system: (a) encoder; (b) decoder.

Lossy Compression

Transform Coding

Wavelet Coding

No blocking

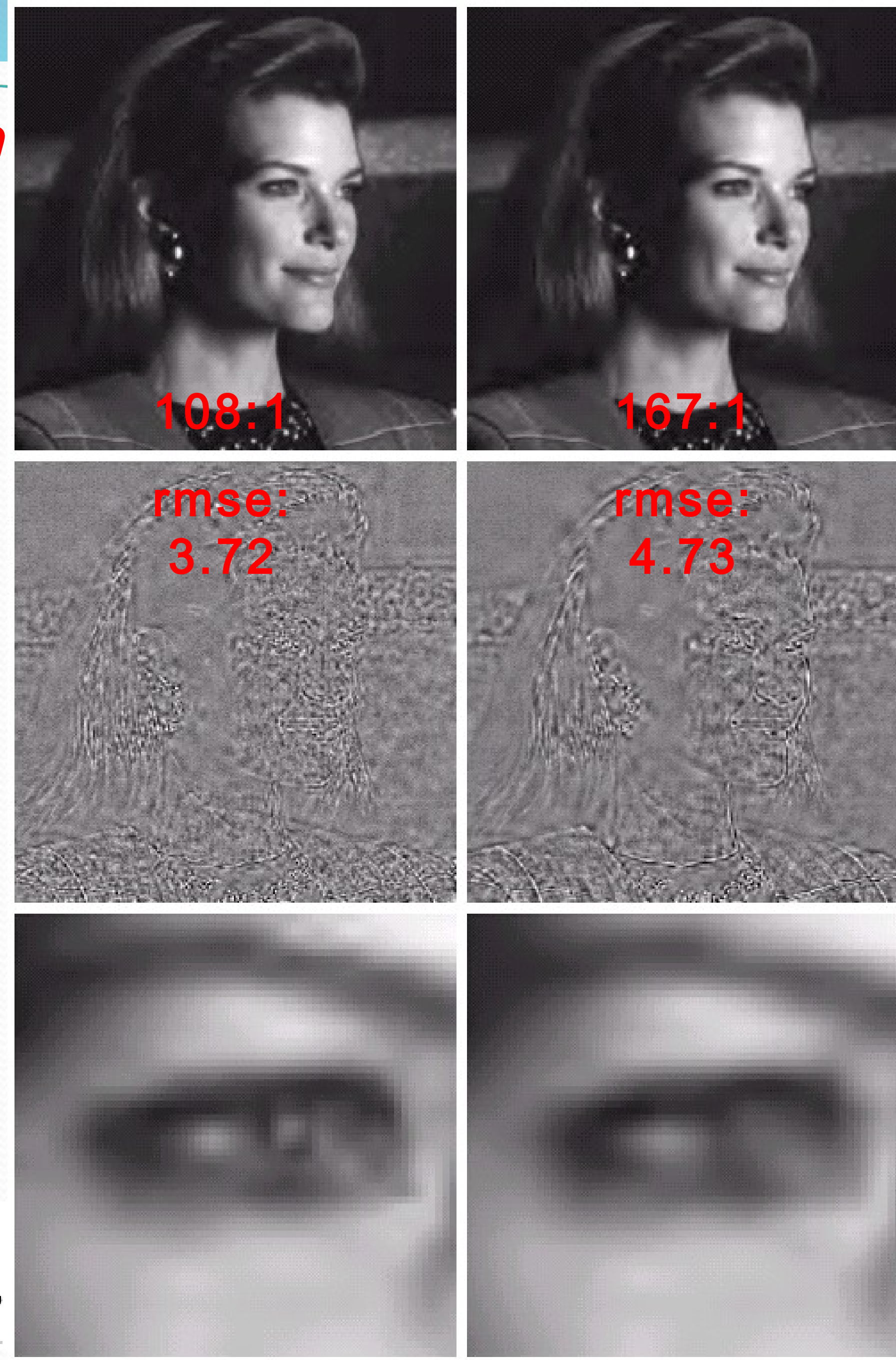
a b
c d
e f

FIGURE 8.40 (a), (c), and (e) Wavelet coding results comparable to the transform-based results in Figs. 8.38(a), (c), and (e); (b), (d), and (f) similar results for Figs. 8.38(b), (d), and (f).

Lossy Compression

Transform Coding

Wavelet Coding



a b
c d
e f

FIGURE 8.41 (a), (c), and (e) Wavelet coding results with a compression ratio of 108 to 1; (b), (d), and (f) similar results for a compression of 167 to 1.

Lossy Compression
Transform Coding

Quantizer selection

Effectiveness of the quantization can be improved by:

• introducing an enlarge quantization interval around zero

• Adapting the size of the quantization interval from scale to scale

FIGURE 8.43 The impact of dead zone interval selection on wavelet coding.

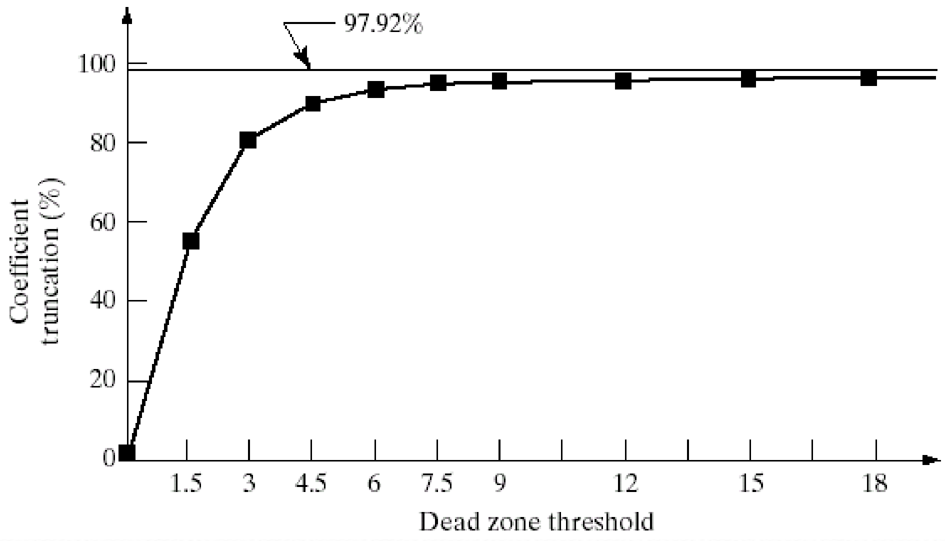


Image Compression Standards

Why Do We Need International Standards?

- International standardization is conducted to achieve inter-operability .
  - Only syntax and decoder are specified.
  - Encoder is not standardized and its optimization is left to the manufacturer.
- Standards provide state-of-the-art technology that is developed by a group of experts in the field.
  - Not only solve current problems, but also anticipate the future application requirements.
- Most of the standards are sanction by the International Standardization Organization (ISO) and the Consultative Committee of the International Telephone and Telegraph (CCITT)

Image Compression Standards
Binary Image Compression Standards

CCITT Group 3 and 4

- They are designed as FAX coding methods.
- The Group 3 applies a non-adaptive 1-D run length coding and optionally 2-D manner.
- Both standards use the same non-adaptive 2-D coding approach, similar to RAC technique.
- They sometime result in data expansion. Therefore, the Joint Bilevel Imaging Group (JBIG), has adopted several other binary compression standards, JBIG1 and JBIG2.

Image Compression Standards
Continues Tone Still Image Comp.

What Is JPEG?

- "Joint Photographic Expert Group". Voted as international standard in 1992.
- Works with color and grayscale images, e.g., satellite, medical, ...
- Lossy and lossless

Image Compression Standards
Continues Tone Still Image Comp. - JPEG

- First generation JPEG uses DCT+Run length Huffman entropy coding.
- Second generation JPEG (JPEG2000) uses wavelet transform + bit plane coding + Arithmetic entropy coding.

Image Compression Standards

Continues Tone Still Image Comp. - JPEG

- Still-image compression standard
- Has 3 lossless modes and 1 lossy mode
  - sequential baseline encoding
    - encode in one scan
    - input & output data precision is limited to 8 bits, while quantized DCT values are restricted to 11 bits
  - progressive encoding
  - hierarchical encoding
  - lossless encoding
- Can achieve compression ratios of up-to 20 to 1 without noticeable reduction in image quality

Image Compression Standards

Continues Tone Still Image Comp. - JPEG

- Work well for continuous tone images, but not good for cartoons or computer generated images.
- Tend to filter out high frequency data.
- Can specify a quality level (Q)
  - with too low Q, resulting images may contain blocky, contouring and ringing structures.
- 5 steps of sequential baseline encoding
  - transform image to luminance/chrominance space (YCbCr)
  - reduce the color components (optional)
  - partition image into 8x8 pixel blocks and perform DCT on each block
  - quantize resulting DCT coefficients
  - variable length code the quantized coefficients

Image Compression Standards

JPEG Encoding

Original

JPEG 27:1

Image Compression Standards
Video Compression Standards

Video compression standards:

1. Video teleconferencing standards
   - H.261 (Px64)
   - H.262
   - H.263 (10 to 30 kbit/s)
   - H.320 (ISDN bandwidth)
2. Multimedia standards
   - MPEG-1 (1.5 Mbit/s)
   - MPEG-2 (2-10 Mbit/s)
   - MPEG-4 (5 to 64 kbit/s for mobile and PSTN and uo to 4 Mbit/s for TV and film application)

THANK

YOU