



Special Module on Media Processing and Communication

Dayalbagh Educational Institute
(DEI)
Dayalbagh Agra

CSM 011

Indian Institute of Technology Delhi
(IITD)
New Delhi

SIV 864



Image Compression

Transform Coding Pipeline

Compression

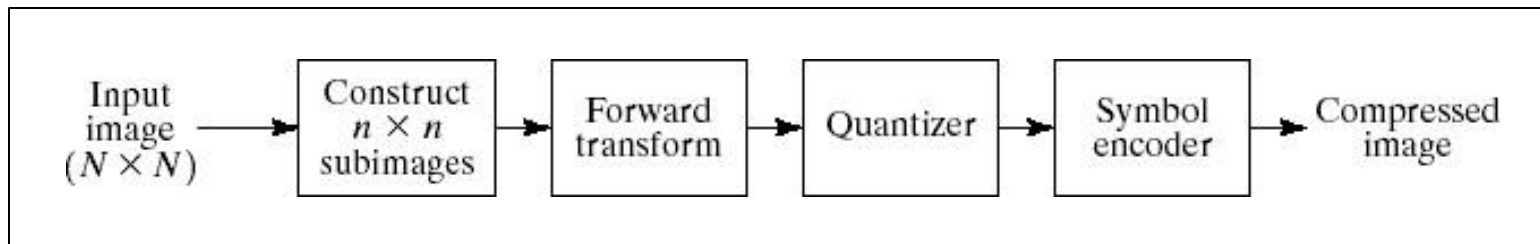




Image Compression

Transform Coding Pipeline

Compression

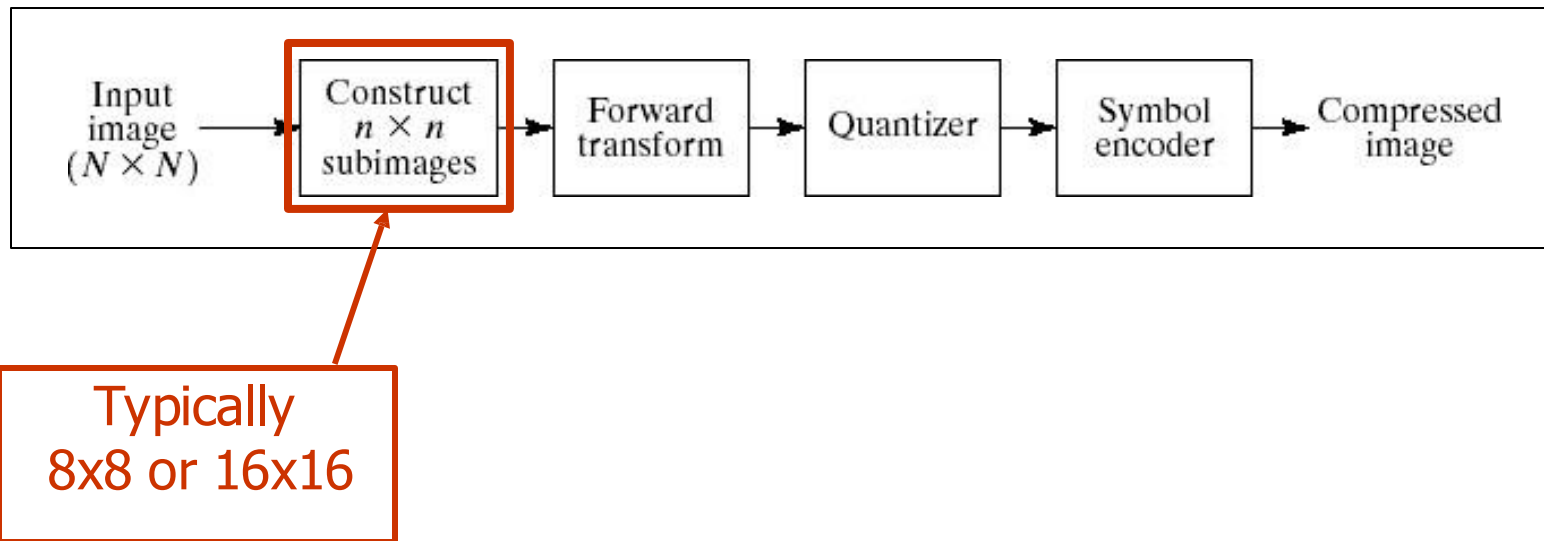
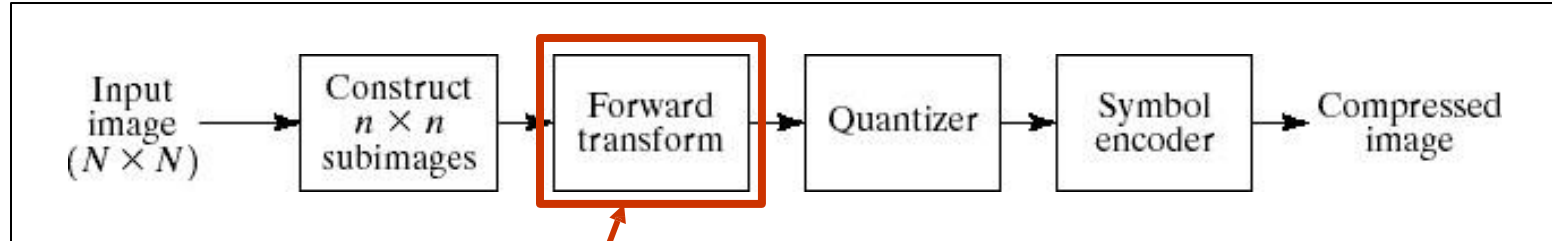




Image Compression

Transform Coding Pipeline

Compression



Discrete Fourier Transform
Discrete Cosine Transform
Karhunen-Loeve Transform

.....



Image Compression

Transform Coding Pipeline

Compression

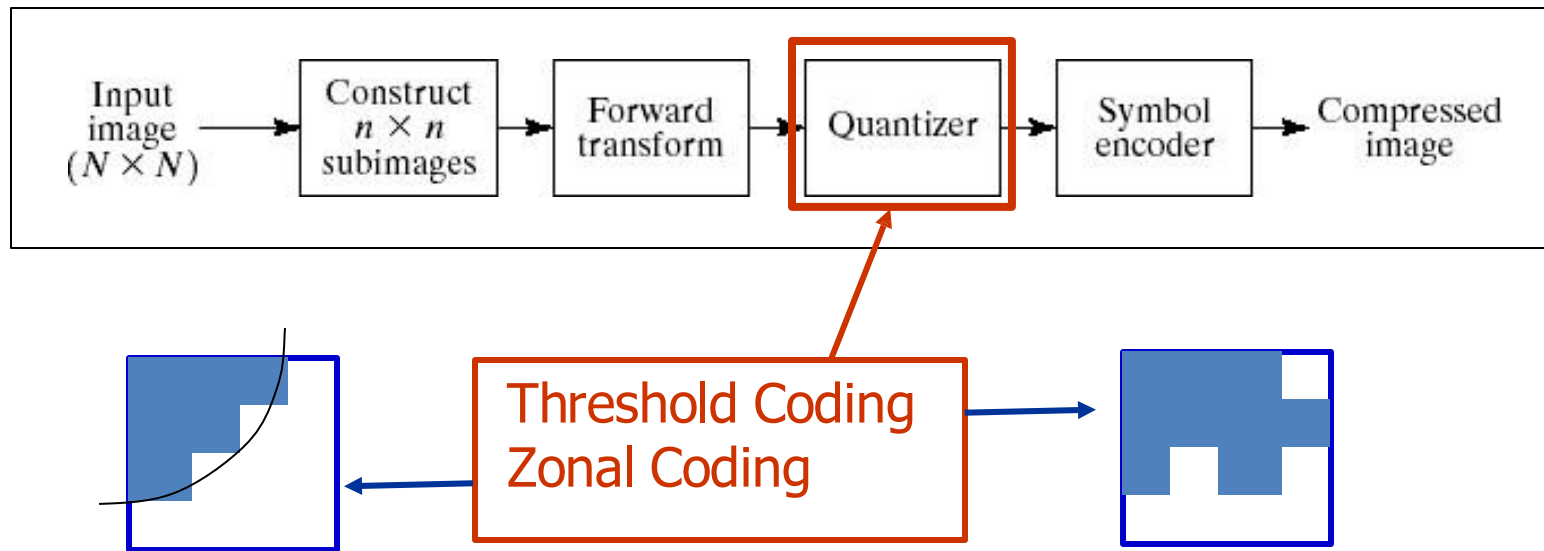




Image Compression

Transform Coding Pipeline

Compression

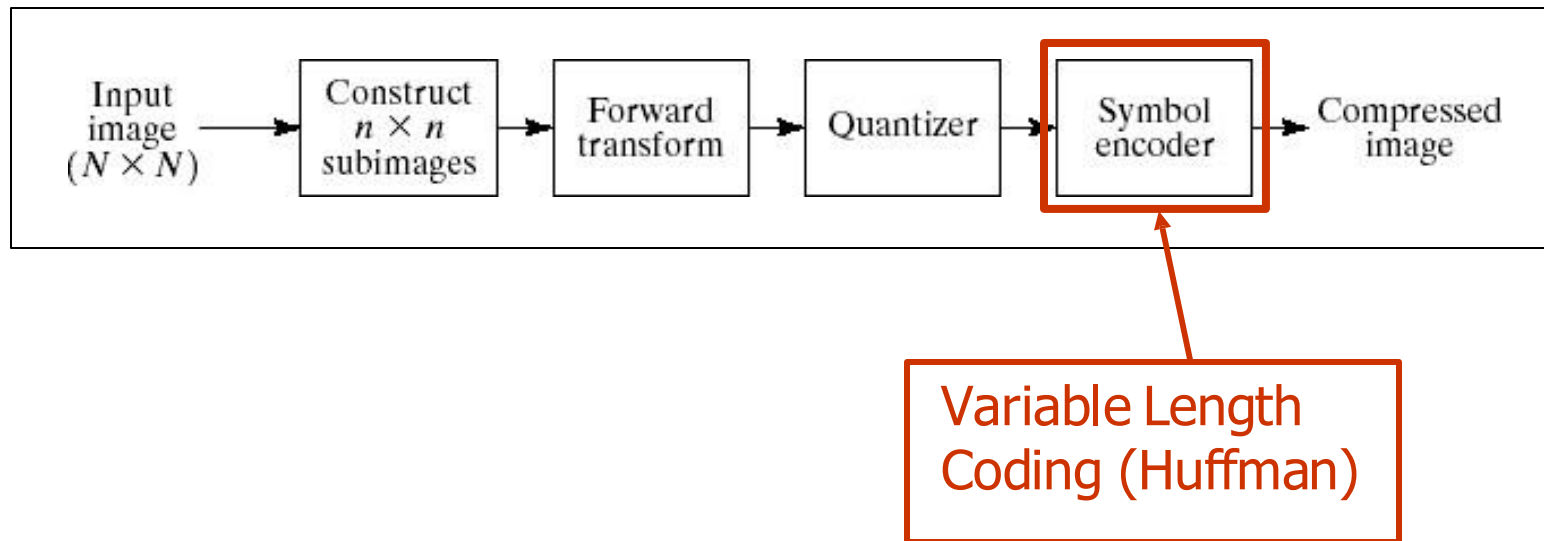
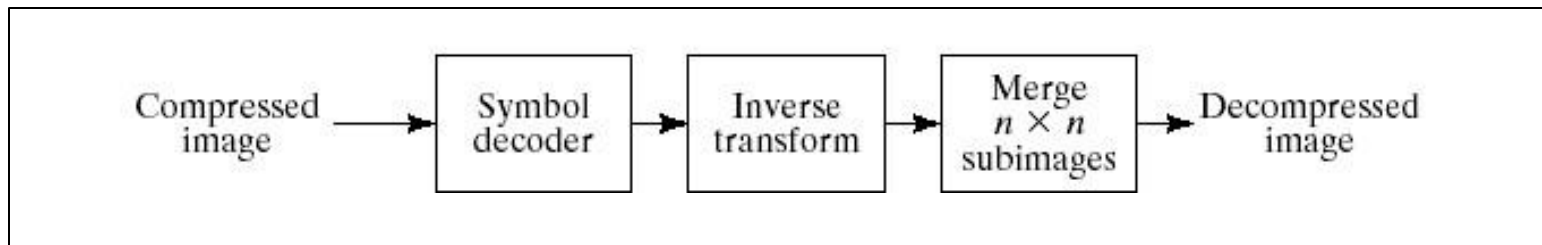
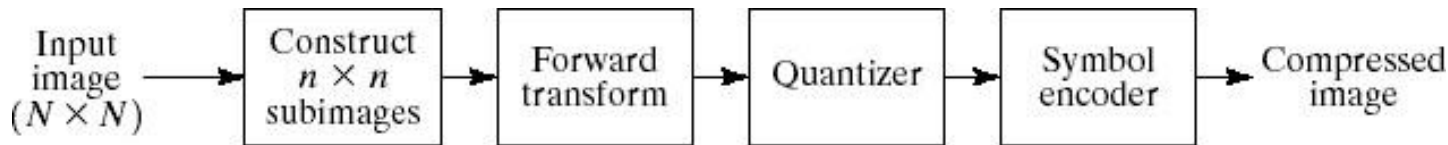




Image Compression

Transform Coding Pipeline

Compression



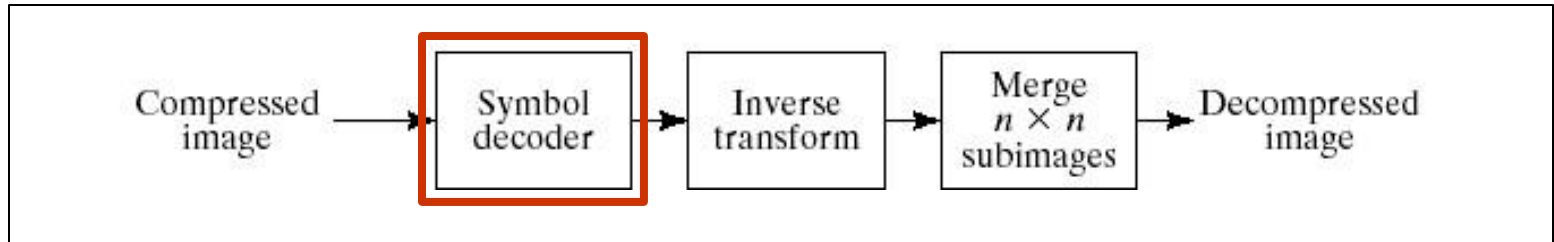
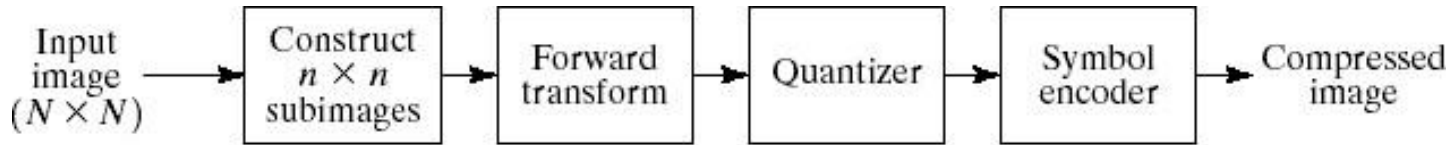
Decompression



Image Compression

Transform Coding Pipeline

Compression



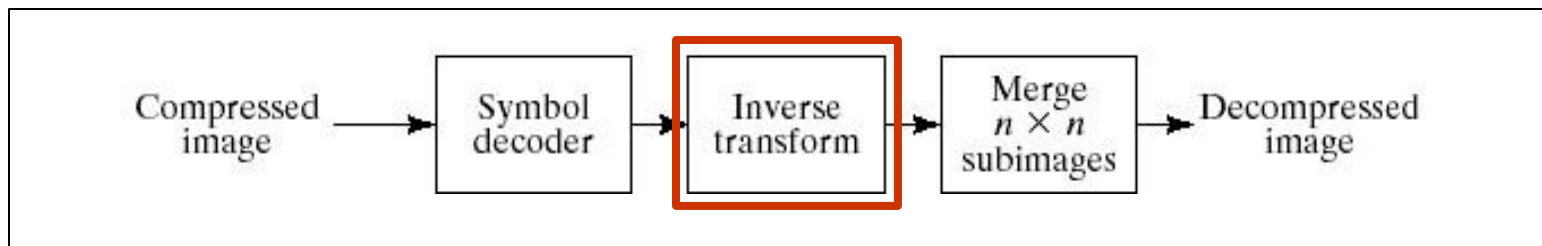
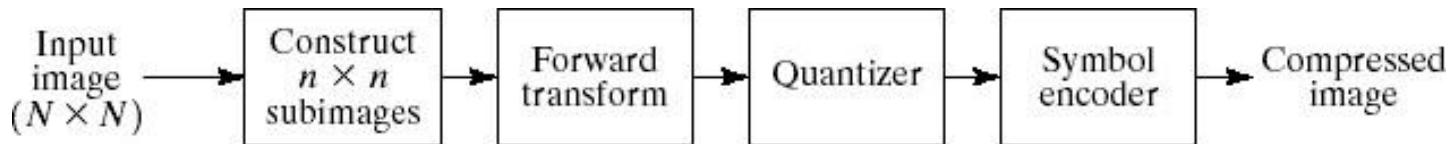
Decompression



Image Compression

Transform Coding Pipeline

Compression



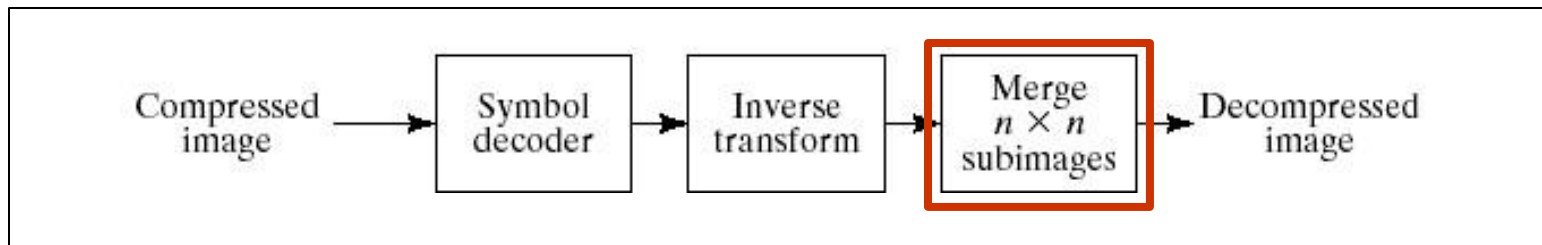
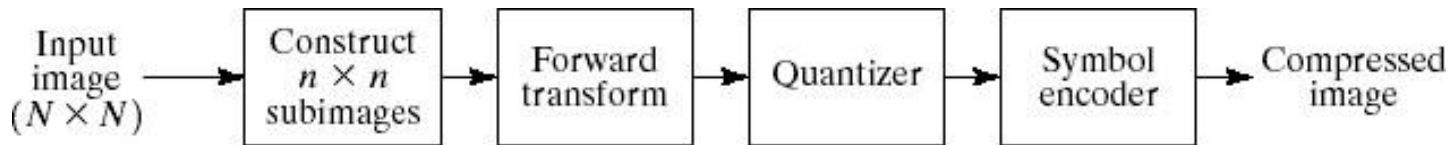
Decompression



Image Compression

Transform Coding Pipeline

Compression



Decompression



Image Compression

JPEG Standard

JPEG - Joint Photographic Experts Group

- Compression of generic continuous-tone still image
- International standard in 1992
- Typical compression 10:1 to 50:1
- Allow for lossy and lossless compression
 - DCT-based lossy compression
 - Predictive-based lossless compression



Image Compression

JPEG Standard





Image Compression

JPEG Standard

Number of modes of operation

Sequential: encoded in left-to-right, top-to-bottom scan

Progressive: encoded in multiple scans to first produce a quick, rough decoded image when the transmission time is long

Hierarchical: encoded at multiple resolution to allow accessing low resolution without full decompression

Lossless : decompressed image is identical to original



Image Compression

JPEG Standard



Sequential



Progressive



Hierarchical



Image Compression

JPEG Standard

► Baseline - Sequential

- Simple, lossy compression
 - DCT-based transform coding pipeline
- Preparation
 - Shift to zero-mean by subtracting 128 → $[-128, 127]$
 - Color space transformation (YCbCr/YUV)
 - Down sampling of color components



Image Compression

JPEG Standard: Steps

Color space transformation

$$Y = 0.3 R + 0.6 G + 0.1 B$$

$$Cb = 0.5 (B - Y) + 0.5$$

$$Cr = (1/1.6) (R - Y) + 0.5$$

Color components can have lower spatial resolution than luminance

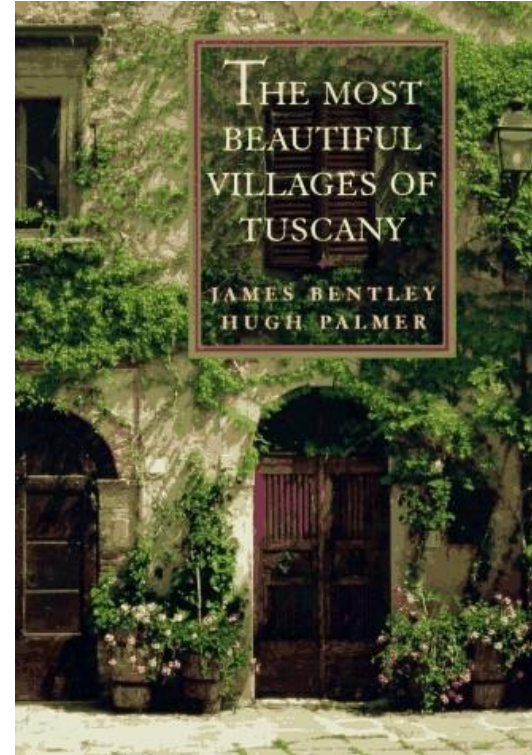
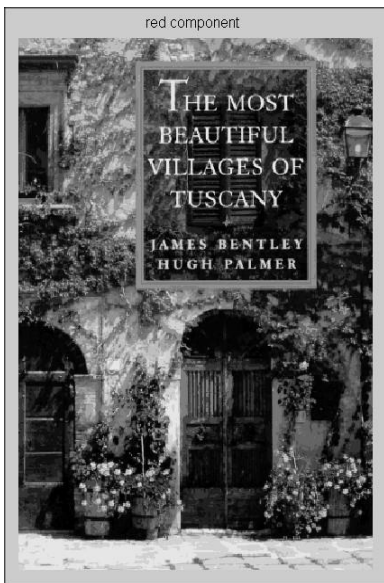




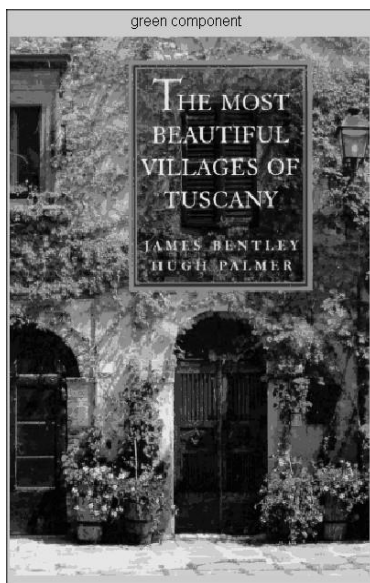
Image Compression

JPEG Standard: Steps

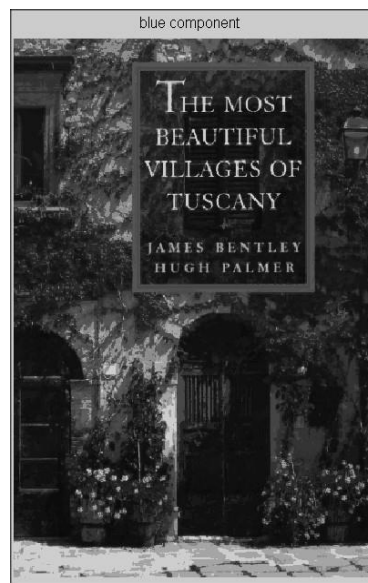
Color space transformation



R



G



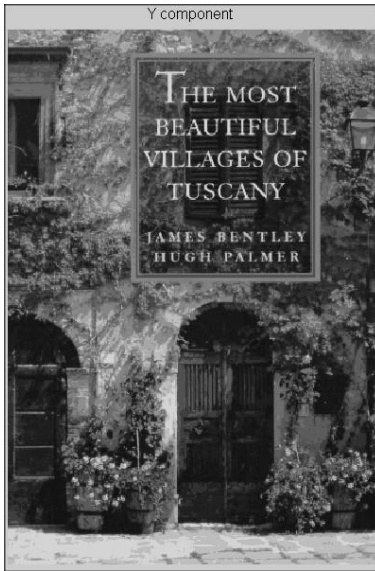
B



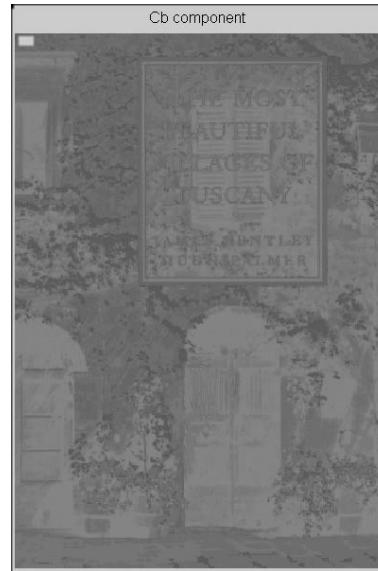
Image Compression

JPEG Standard: Steps

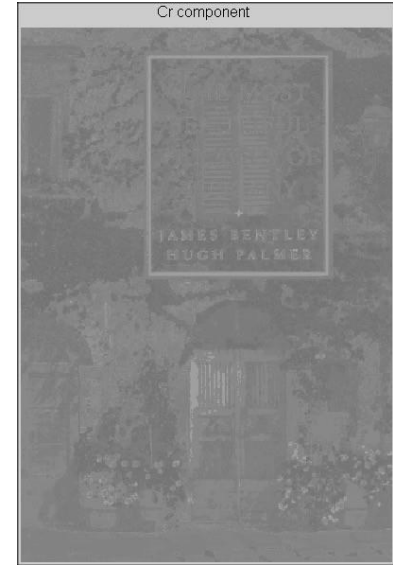
Color space transformation



Y



Cb



Cr



Image Compression

JPEG Standard: Steps

Down sampling

- 4-2-2

Y 

Cb/Cr 

- 4-1-1

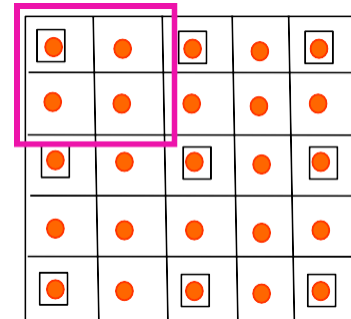
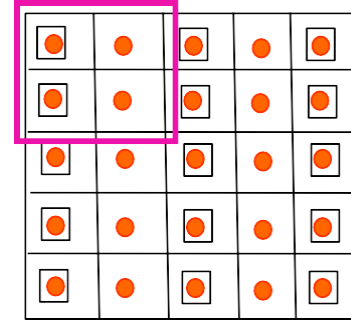




Image Compression

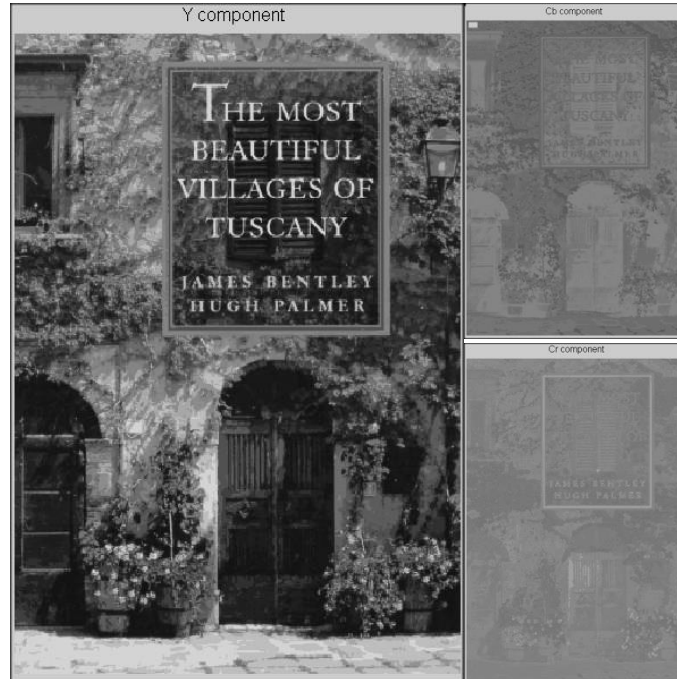
JPEG Standard: Steps

Down sampling

Example

4-1-1

Y



Cb

Cr



Image Compression

JPEG Standard: Steps

Divide image in to sub images

Subimage
of size 8x8

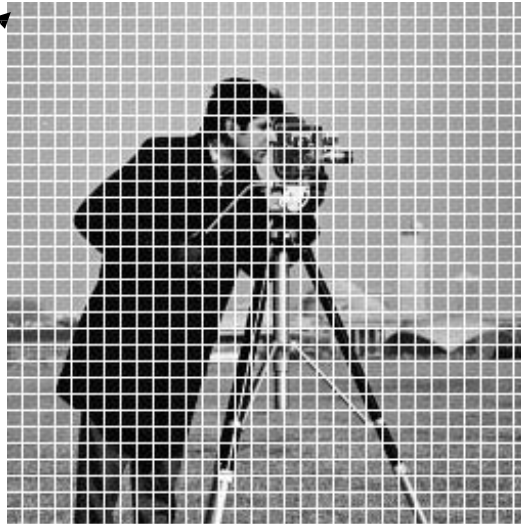


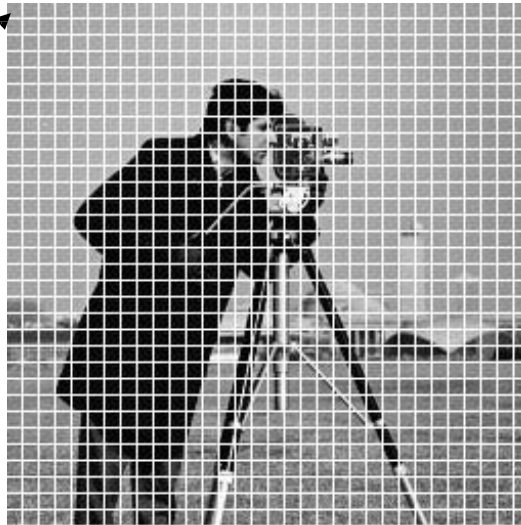


Image Compression

JPEG Standard: Steps

Divide image in to sub images

Subimage
of size 8x8



What if the image size is not
a multiple of 8x8 block?



Image Compression

JPEG Standard: Steps

Divide image in to sub images

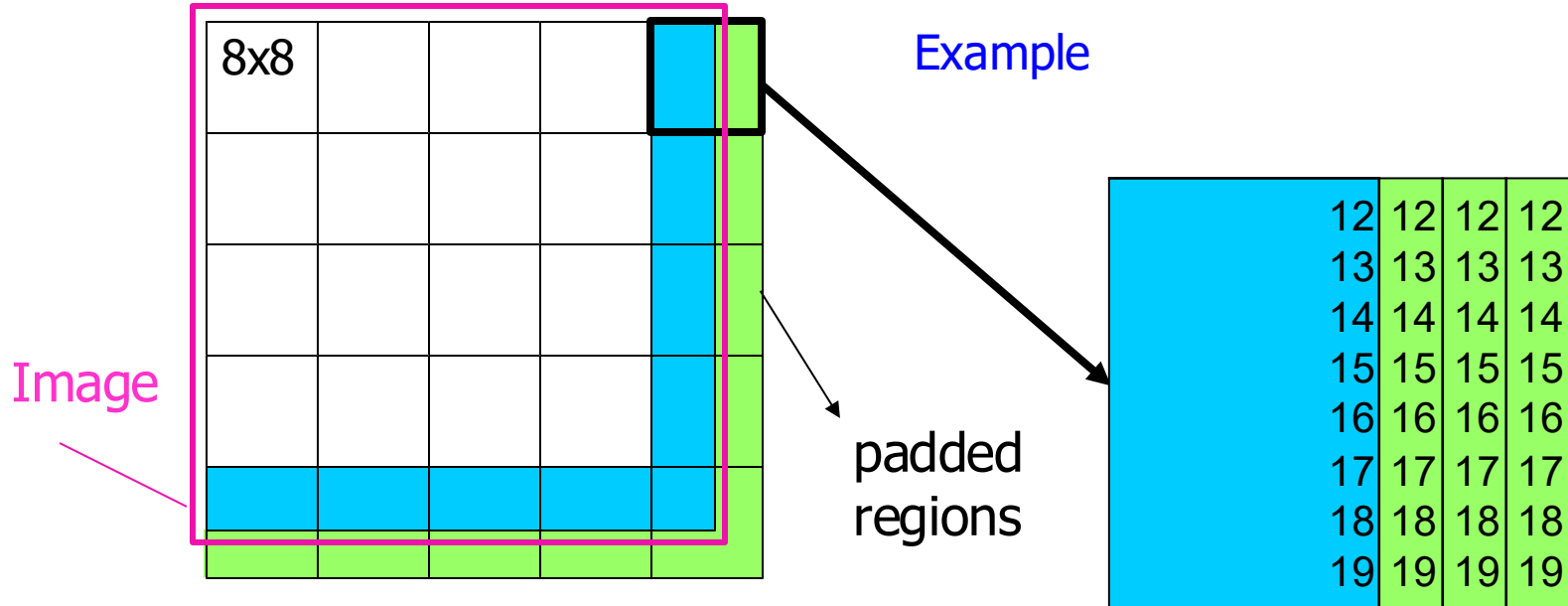




Image Compression

JPEG Standard: Steps

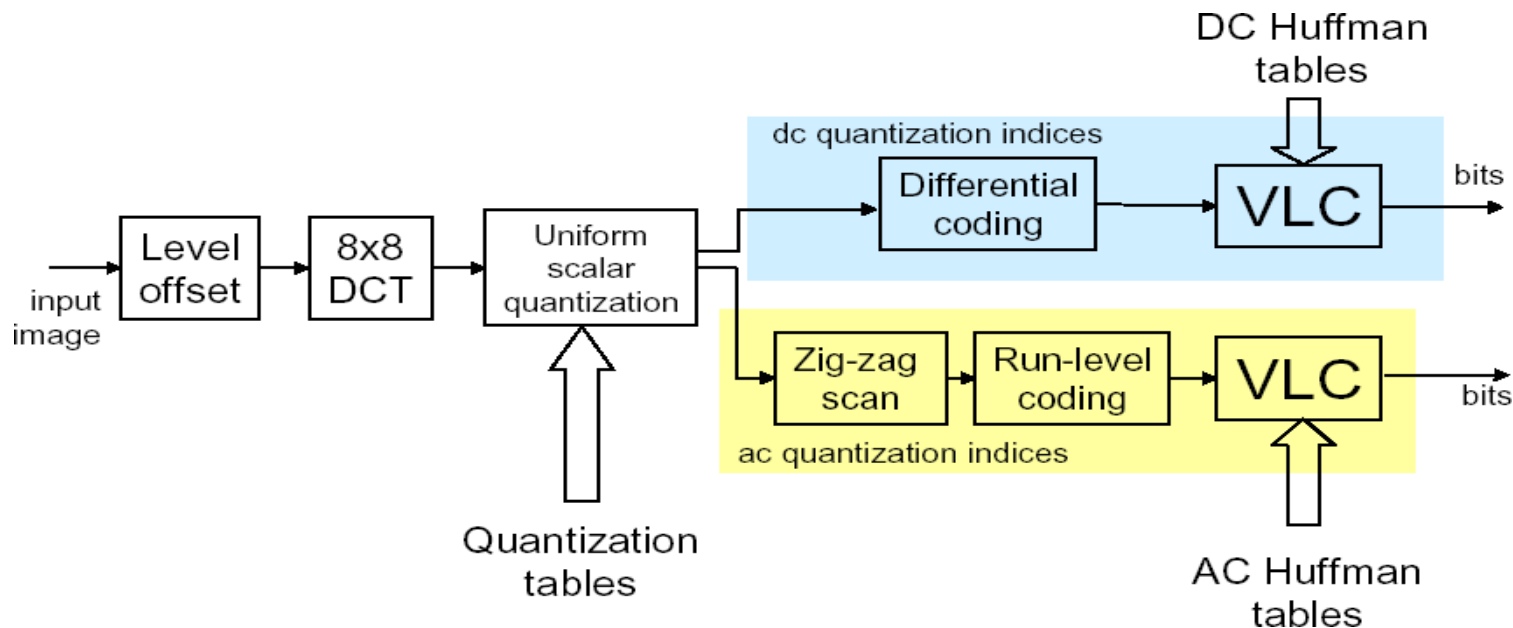




Image Compression

JPEG Standard: Steps

Example

Image

183	160	94	153	194	163	132	165
183	153	116	176	187	166	130	169
179	168	171	182	179	170	131	167
177	177	179	177	179	165	131	167
178	178	179	176	182	164	130	171
179	180	180	179	183	169	132	169
179	179	180	182	183	170	129	173
180	179	181	179	181	170	130	169



Image Compression

JPEG Standard: Steps

Preparation Shift to zero-mean by subtracting 128

183	160	94	153	194	163	132	165	55	32	-34	25	66	35	4	37
183	153	116	176	187	166	130	169	55	25	-12	48	59	38	2	41
179	168	171	182	179	170	131	167	51	40	43	54	51	42	3	39
177	177	179	177	179	165	131	167	49	49	51	49	51	37	3	39
178	178	179	176	182	164	130	171	50	50	51	48	54	36	2	43
179	180	180	179	183	169	132	169	51	52	52	51	55	41	4	41
179	179	180	182	183	170	129	173	51	51	52	54	55	42	1	45
180	179	181	179	181	170	130	169	52	51	53	51	53	42	2	41

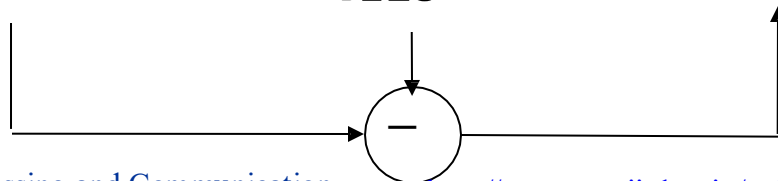




Image Compression

JPEG Standard: Steps

Preparation Shift to zero-mean by subtracting 128

183	160	94	153	194	163	132	165	55	32	-34	25	66	35	4	37
183	153	116	176	187	166	130	169	55	25	-12	48	59	38	2	41
179	168	171	182	179	170	131	167	51	40	43	54	51	42	3	39
177	177	179	177	179	165	131	167	49	49	51	49	51	37	3	39
178	178	179	176	182	164	130	171	50	50	51	48	54	36	2	43
179	180	180	179	183	169	132	169	51	52	52	51	55	41	4	41
179	179	180	182	183	170	129	173	51	51	52	54	55	42	1	45
180	179	181	179	181	170	130	169	52	51	53	51	53	42	2	41

128

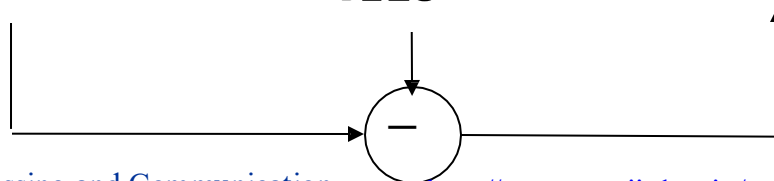




Image Compression

JPEG Standard: Steps

Forward DCT

55	32	-34	25	66	35	4	37	313	56	-27	18	78	-60	27	-27
55	25	-12	48	59	38	2	41	-38	-27	13	44	32	-1	-24	-10
51	40	43	54	51	42	3	39	-20	-17	10	33	21	-6	-16	-9
49	49	51	49	51	37	3	39	-10	-8	9	17	9	-10	-13	1
50	50	51	48	54	36	2	43	-6	1	6	4	-3	-7	-5	5
51	52	52	51	55	41	4	41	2	3	0	-3	-7	-4	0	3
51	51	52	54	55	42	1	45	4	4	-1	-2	-9	0	2	4
52	51	53	51	53	42	2	41	3	1	0	-4	-2	-1	3	1

8 × 8
DCT



Image Compression

JPEG Standard: Steps

Quantization

Q-table : specifies quantization stepsize

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



Image Compression

JPEG Standard: Steps

Quantization

Q-table : specifies quantization stepsize

- Q-table can be specified by **user**
- Q-table is scaled up/down by a chosen **quality factor**
- Quantization stepsize Q_{ij} is **dependent** on the coordinates (i,j) within the 8-by-8 block
- Quantization stepsize Q_{ij} **increases** from top-left to bottom-right



Image Compression

JPEG Standard: Steps

Quantization

X_{ij}

S_{ij}

313	56	-27	18	78	-60	27	-27
-38	-27	13	44	32	-1	-24	-10
-20	-17	10	33	21	-6	-16	-9
-10	-8	9	17	9	-10	-13	1
-6	1	6	4	-3	-7	-5	5
2	3	0	-3	-7	-4	0	3
4	4	-1	-2	-9	0	2	4
3	1	0	-4	-2	-1	3	1

20	5	-3	1	3	-2	1	0
-3	-2	1	2	1	0	0	0
-1	-1	1	1	1	0	0	0
-1	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

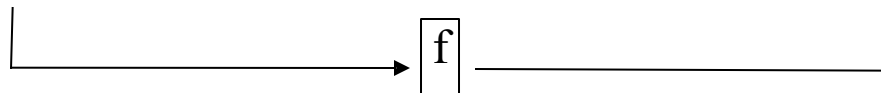




Image Compression

JPEG Standard: Steps

Quantization

X_{ij}

S_{ij}

313	56	-27	18	78	-60	27	-27
-38	-27	13	44	32	-1	-24	-10
-20	-17	10	33	21	-6	-16	-9
-10	-8	9	17	9	-10	-13	1
-6	1	6	4	-3	-7	-5	5
2	3	0	-3	-7	-4	0	3
4	4	-1	-2	-9	0	2	4
3	1	0	-4	-2	-1	3	1

20	5	-3	1	3	-2	1	0
-3	-2	1	2	1	0	0	0
-1	-1	1	1	1	0	0	0
-1	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

$q_{ij} = 11$

f



Image Compression

JPEG Standard: Steps

Quantization

X_{ij}

313	56	-27	18	78	-60	27	-27
-38	-27	13	44	32	-1	-24	-10
-20	-17	10	33	21	-6	-16	-9
-10	-8	9	17	9	-10	-13	1
-6	1	6	4	-3	-7	-5	5
2	3	0	-3	-7	-4	0	3
4	4	-1	-2	-9	0	2	4
3	1	0	-4	-2	-1	3	1

S_{ij}

20	5	-3	1	3	-2	1	0
-3	-2	1	2	1	0	0	0
-1	-1	1	1	1	0	0	0
-1	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

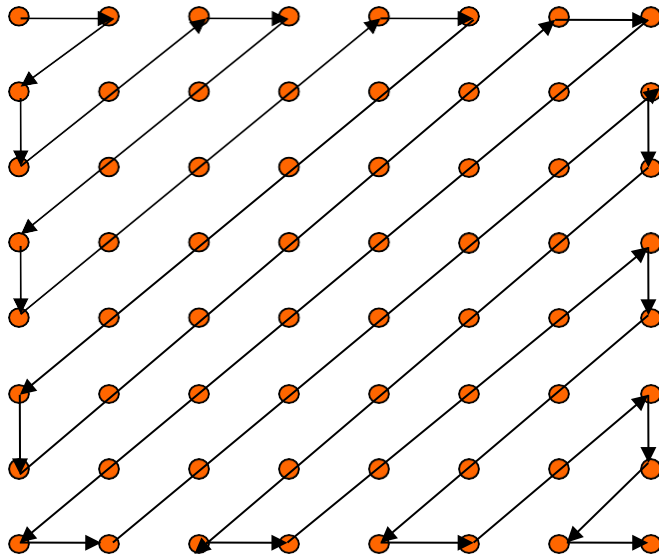
f



Image Compression

JPEG Standard: Steps

Quantization



Zigzag Scan

20	5	-3	1	3	-2	1	0
-3	-2	1	2	1	0	0	0
-1	-1	1	1	1	0	0	0
-1	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

zigzag scan

(20,5,-3,-1,-2,-3,1,1,-1,-1,
0,0,1,2,3,-2,1,1,0,0,0,0,0,
0,1,1,0,1,EOB)

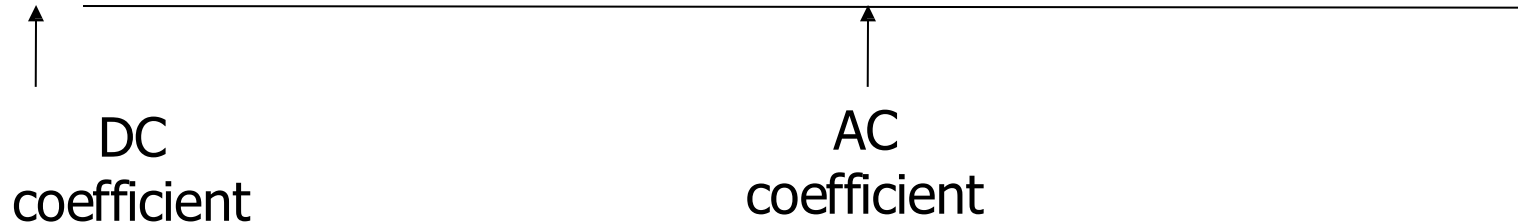


Image Compression

JPEG Standard: Steps

Differential Coding, Run Length Coding, Variable Length Coding

(20,5,-3,-1,-2,-3,1,1,-1,-1,0,0,1,2,3,-2,1,1,0,0,0,0,0,0,1,1,0,1,EOB)



- DC coefficient : Differential coding
- AC coefficient : run-length coding (run, level)
→ Huffman coding



Image Compression

JPEG Standard: Steps

Decompression

(20,5,-3,-1,-2,-3,1,1,-1,-1,0,0,1,2,3,-2,1,1,0,0,0,0,0,0,1,1,0,1,EOB)

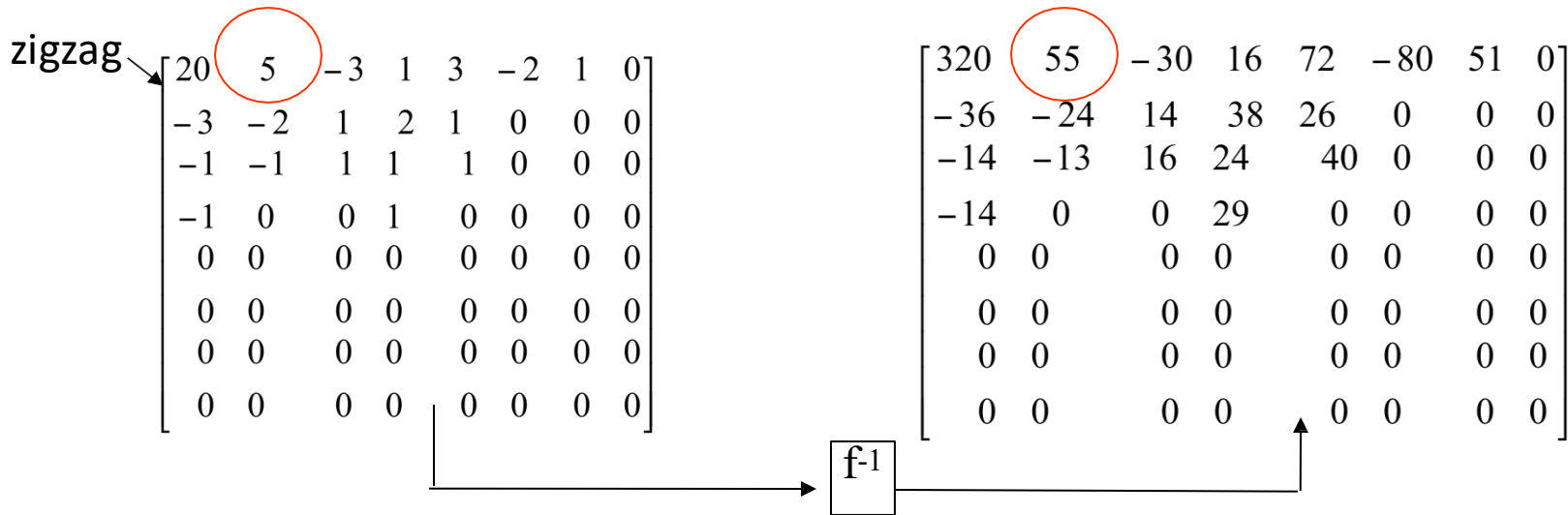




Image Compression

JPEG Standard: Steps

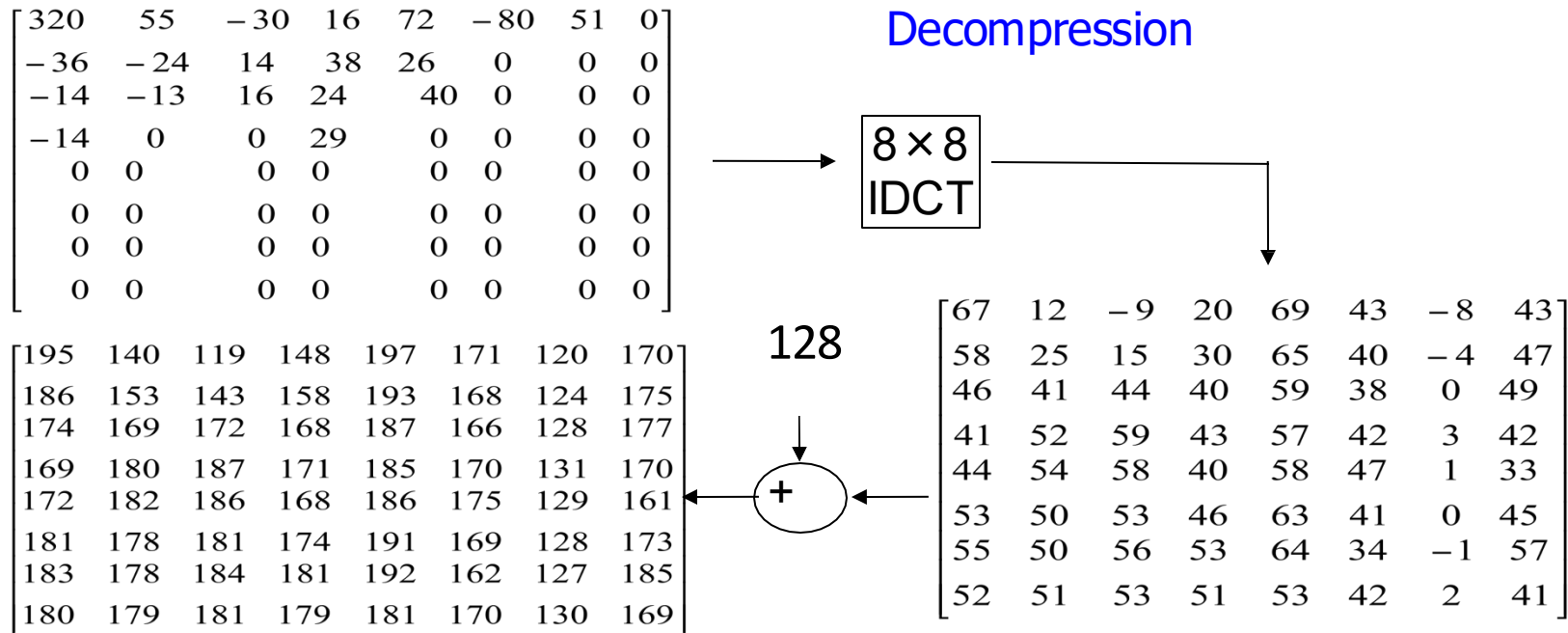




Image Compression

JPEG Standard: Steps

$$\begin{bmatrix} 183 & 160 & 94 & 153 & 194 & 163 & 132 & 165 \\ 183 & 153 & 116 & 176 & 187 & 166 & 130 & 169 \\ 179 & 168 & 171 & 182 & 179 & 170 & 131 & 167 \\ 177 & 177 & 179 & 177 & 179 & 165 & 131 & 167 \\ 178 & 178 & 179 & 176 & 182 & 164 & 130 & 171 \\ 179 & 180 & 180 & 179 & 183 & 169 & 132 & 169 \\ 179 & 179 & 180 & 182 & 183 & 170 & 129 & 173 \\ 180 & 179 & 181 & 179 & 181 & 170 & 130 & 169 \end{bmatrix} \times \begin{bmatrix} 195 & 140 & 119 & 148 & 197 & 171 & 120 & 170 \\ 186 & 153 & 143 & 158 & 193 & 168 & 124 & 175 \\ 174 & 169 & 172 & 168 & 187 & 166 & 128 & 177 \\ 169 & 180 & 187 & 171 & 185 & 170 & 131 & 170 \\ 172 & 182 & 186 & 168 & 186 & 175 & 129 & 161 \\ 181 & 178 & 181 & 174 & 191 & 169 & 128 & 173 \\ 183 & 178 & 184 & 181 & 192 & 162 & 127 & 185 \\ 180 & 179 & 181 & 179 & 181 & 170 & 130 & 169 \end{bmatrix}$$

X $\hat{X}$

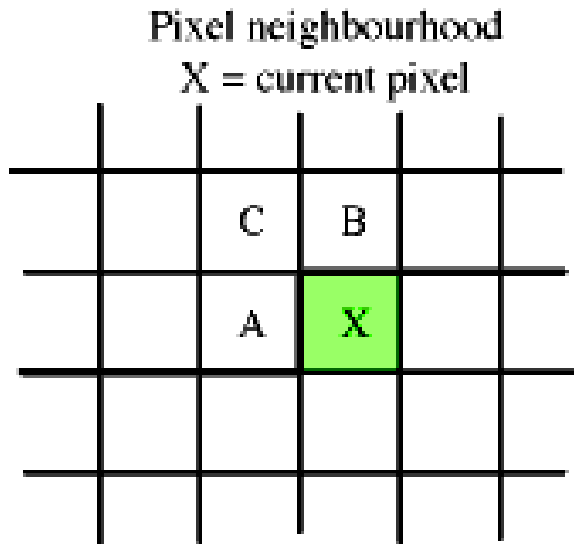
Distortion calculation: $MSE = ||X - \hat{X}||^2$



Image Compression

JPEG Standard

Predictive Lossless



Encoder type	Prediction method
0	no prediction
1	A
2	B
3	C
4	$A + B - C$
5	$A + ((B - C) / 2)$
6	$B + ((A - C) / 2)$
7	$(A + B) / 2$



Image Compression

JPEG 2000



JPEG: DCT



JPEG 2000: Wavelets