IMAGE COMPRESSION STANDARD

JPEG

Image Compression

Reduces amount of data required to represent a digital image

How to reduce?

By Removing the redundant data

REDUNDANCIES

- Coding Redundancy
  - Gray levels of the image uses more code symbols than really needed
  - Similar to Data Compression

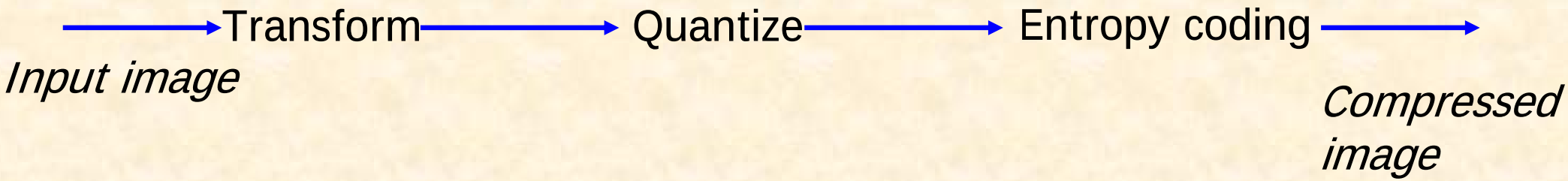
- Interpixel Redundancy
  - Results from structural or geometric relationships between objects in image

- Psychovisual Redundancy
  - Our eyes does not respond to all visual information

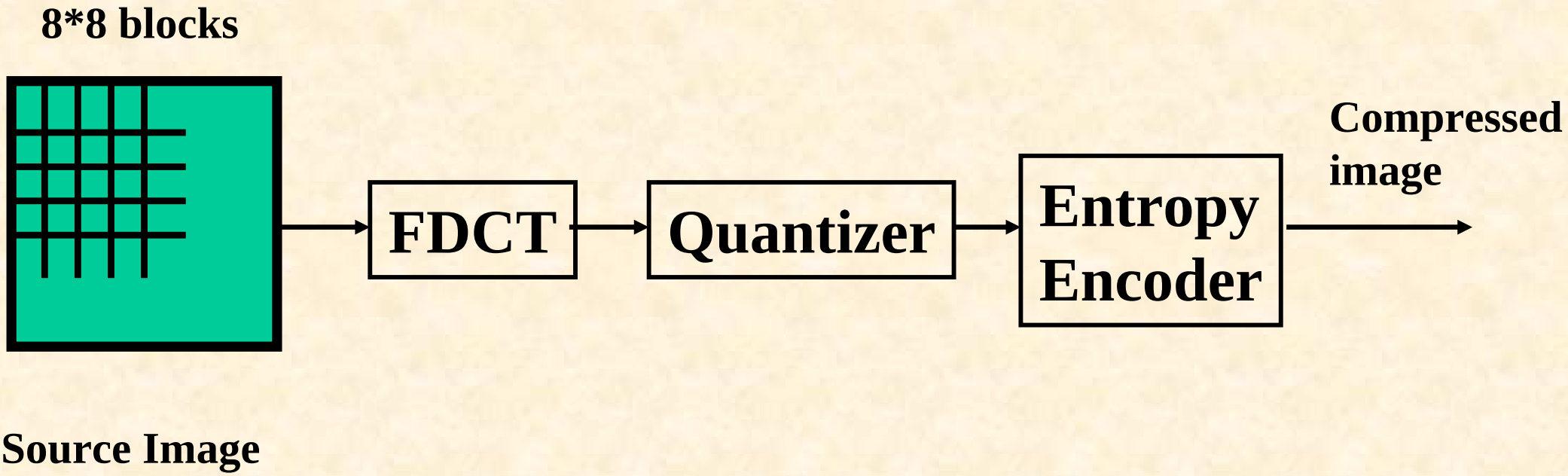
- Two types of compression
  - Lossless – Entropy coding
  - Lossy – Eliminates Psychovisual redundancies
- Three types of Lossy compression
  - Transform coding
  - Vector Quantization
  - Fractal coding

JPEG

- Joint Photographic Experts Group
- Performs Transform coding
  - Transforms to frequency domain

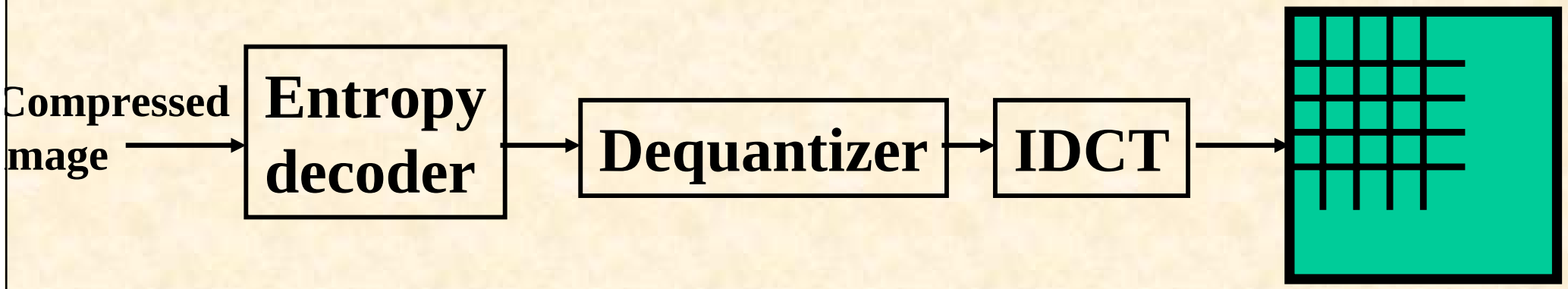


JPEG Encoder



FDCT-Forward Discrete Cosine Transform

JPEG Decoder



IDCT-Inverse Discrete Cosine Transform

JPEG - DCT – Based Image Compression

- An image is broken into 8*8 blocks
- Pixels are level shifted by 2^{n-1} , where 2^n is max gray level
- DCT Transform is computed on each block
- DCT coefficients are quantized
- Entropy coded (Lossless coding)

Discrete Cosine Transform

Forward Discrete Transform

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

f(x,y) **represents pixel value**

where

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

$$\alpha(u) = \begin{cases} \sqrt{\frac{1}{N}} & for\ u = 0 \\ \sqrt{\frac{2}{N}} & for\ u = 1,2,\ldots,N-1 \end{cases}$$

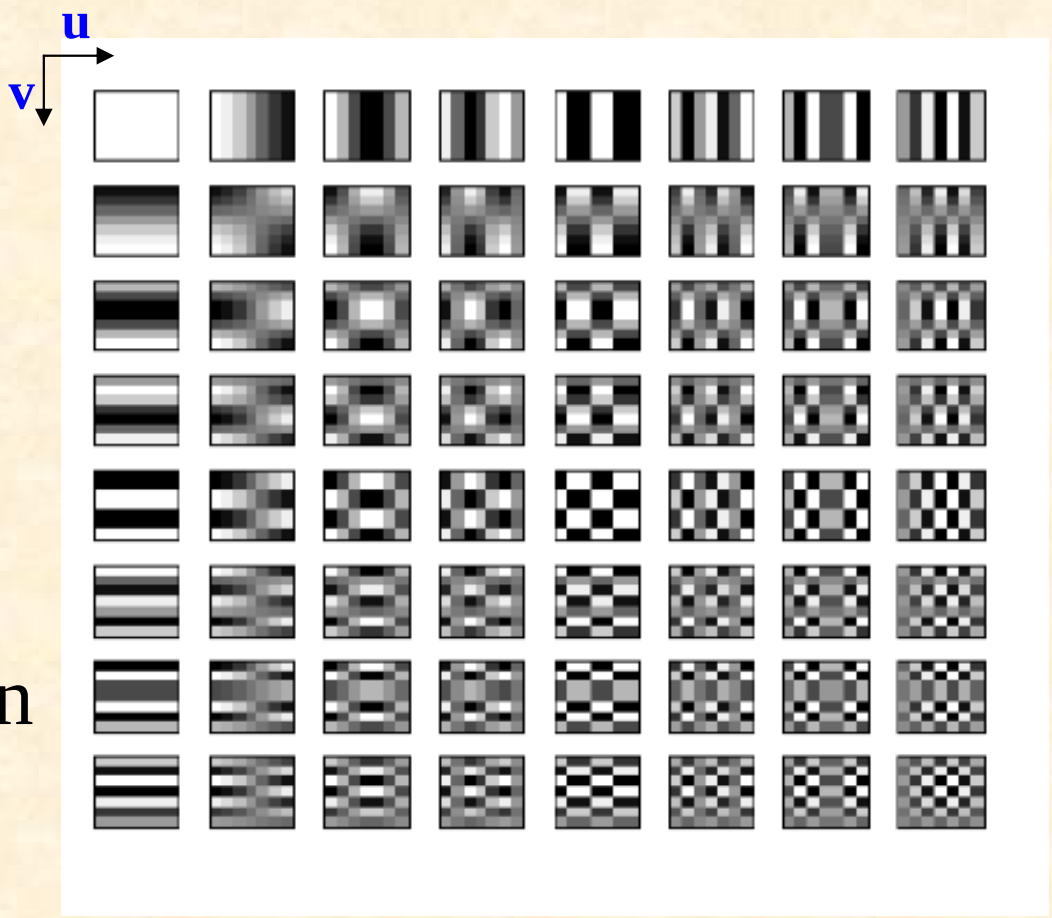
DCT basis patterns

- Any 8x8 block of pixels can be represented as a sum of 64 basis patterns

- Output of the DCT is the set of weights for these basis patterns (the DCTcoefficients)

- Multiply each basis pattern by its weight and add them together

- Result is the original image block



Sample 8*8 block

52	55	61	66	70	61	64	73
63	59	66	90	109	85	69	72
62	59	68	113	114	104	66	73
63	58	71	122	154	106	70	69
67	61	68	104	126	88	68	70
79	65	60	70	77	68	58	75
85	71	64	59	55	61	65	83
87	79	69	68	65	76	78	94

Level Shifted by -128

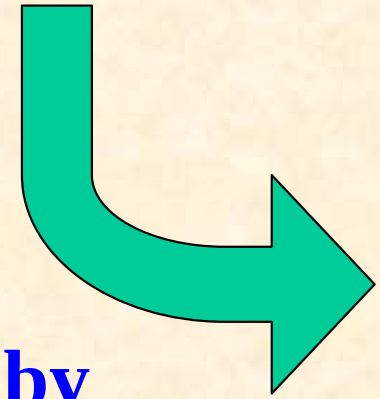
-76	-73	-67	-62	-58	-67	-64	-55
-65	-69	-62	-38	-19	-43	-59	-56
-66	-69	-60	-15	16	-24	-62	-55
-65	-70	-57	-6	26	-22	-58	-59
-61	-67	-60	-24	-2	-40	-60	-58
-49	-63	-68	-58	-51	-65	-70	-53
-43	-57	-64	-69	-73	-67	-63	-45
-41	-49	-59	-60	-63	-52	-50	-34

DCT Co-efficients (After transform)

-415	-29	-62	25	55	-20	-1	3
7	-21	-62	9	11	-7	-6	6
-46	8	77	-25	-30	10	7	-5
-50	13	35	-15	-9	6	0	3
11	-8	-13	-2	-1	1	-4	1
-10	1	3	-3	-1	0	2	-1
-4	-1	2	-1	2	-3	1	-2
-1	-1	-1	-2	-1	-1	0	-1

DC co-efficient

Quantization table

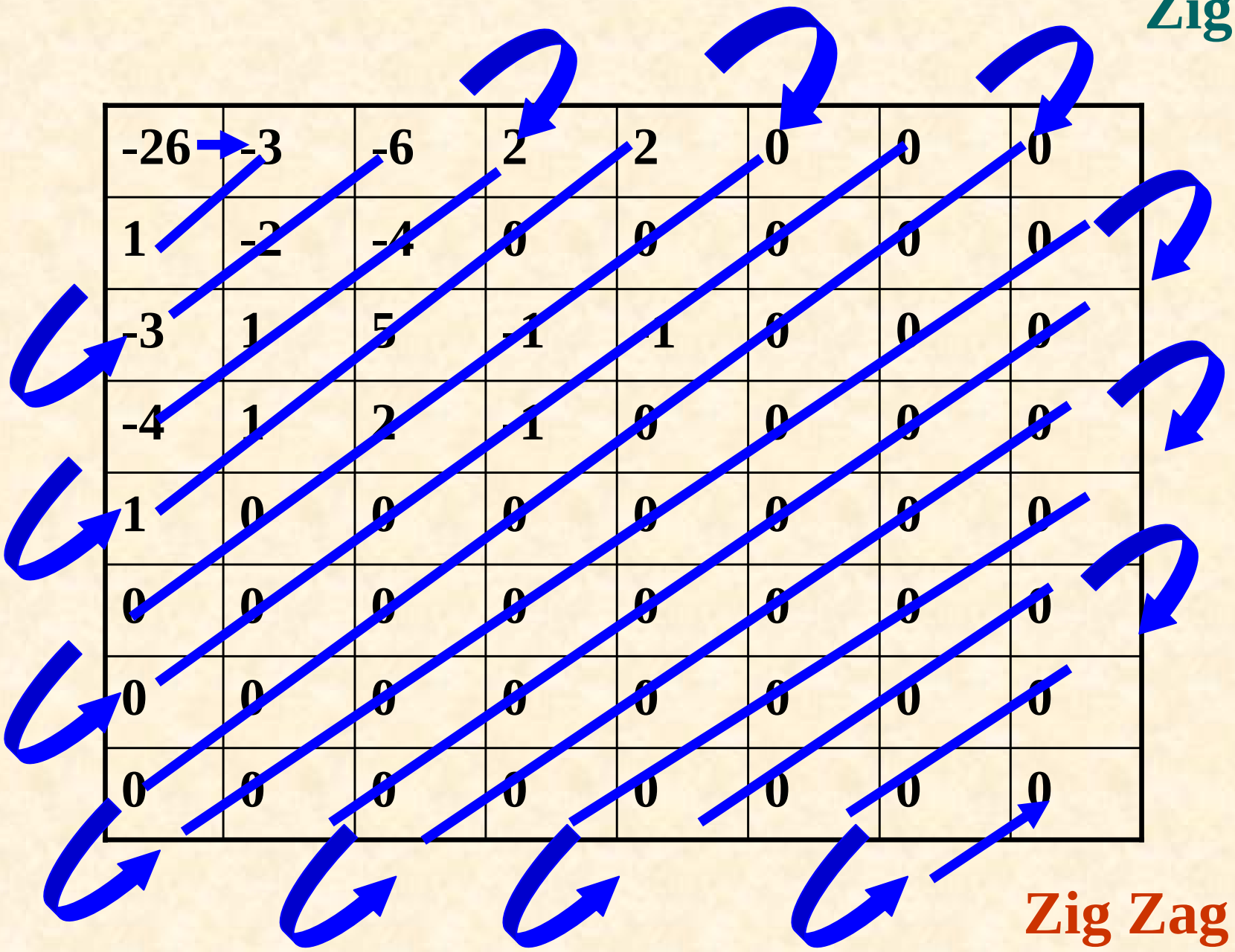


Divided by

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

Quantized co-efficients

Zig zag scan



-26	-3	-6	2	2	0	0	0
1	-2	-4	0	0	0	0	0
-3	1	5	-1	-1	0	0	0
-4	1	2	-1	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

Zig Zag Scan o/p

-26 3 1 3 -2 -6 2 -4 1 -4 1 1 5 0 2 0 0 -1 2 0 0 0 0 0 1 1 EOB

- Zig Zag scan is done so that the coefficients are in order of increasing frequency.
- The higher frequency coefficients are more likely to be 0 after quantization.
- This improves the compression of run-length encoding.

Entropy coding

- DC co-efficients are difference coded
  - Difference between current DC co-efficient and previously coded subimage DC co-efficient is found out
  - And then huffman coded by refering DC code table
- Non Zero AC co-efficients are coded using variable length coding
  - Run length coded
  - And then huffman coded

Entropy coding

Jpeg co-efficients coding categories

Range	DC Difference category	AC category
0	0	N/A
-1,1	1	1
-3,-2,2,3	2	2
-7,…-4,4,…7	3	3
…..	….	….
….	…..	….
-32767,…-16384, 16384,…32767	F	N/A

JPEG default DC code

Category	Base code	Length
0	010	3
1	011	4
2	100	5
…	…	…
….	….	…
B	111111110	20

DC co-efficient coding

- To code DC difference code -9
- Category is 4
- Base code is 101
- Remaining length 4 bits is generated from LSB if positive or LSBs of negative difference minus 1
  - (0111-1=0110)

  Total code 1010110

Jpeg co-efficients coding categories

Range	DC Difference category	AC category
0	0	N/A
-1,1	1	1
-3,-2,2,3	2	2
-7,…-4,4,…7	3	3
-15,…-6,6,…15	4	4
….	…..	….
-32767,…-16384, 16384,…32767	F	N/A

JPEG default DC code

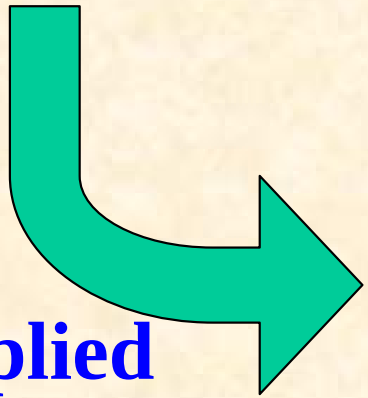
AC Co-efficient coding

- AC Huffman code depends on the number of Zero valued co-efficients preceding non zero co-efficient to be coded and magnitude category of non–zero co-efficient
- Eg (0 0 0 3 0 -9) is categorized as (run,category) (3/2,1/4)
- This is coded using Jpeg AC code table as coded in previous case(DC)

Decoding Stage

The coded data is entropy decoded in the decoder

-26	-3	-6	2	2	0	0	0
1	-2	-4	0	0	0	0	0
-3	1	5	-1	-1	0	0	0
-4	1	2	-1	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



Multiplied by

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

Denormalized co-efficients

-416	-33	-60	32	48	0	0	0
12	-24	-56	0	0	0	0	0
-42	13	80	-24	-40	0	0	0
-56	17	44	-29	0	0	0	0
18	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

After Inverse DCT

-70	-64	-61	-64	-69	-66	-58	-50
-72	-73	-61	-39	-30	-40	-54	-59
-68	-78	-58	-9	13	-12	-48	-64
-59	-77	-57	0	22	-13	-51	-60
-54	-75	-64	-23	-13	-44	-63	-56
-52	-71	-72	-54	-54	-71	-71	-54
-45	-59	-70	-68	-67	-67	-61	-50
-35	-47	-61	-66	-60	-48	-44	-44

After level shifting (reconstructed subimage)

58	64	67	59	62	68	70	78
56	55	67	89	98	88	74	69
60	50	70	119	141	116	80	64
69	51	71	128	149	115	77	68
74	53	64	105	115	84	65	72
76	57	56	74	75	57	57	74
83	69	59	60	61	61	67	78
93	81	67	62	69	80	84	84

Difference between original and reconstructed subimage

-6	-9	-6	2	11	-1	-6	-5
7	4	-1	1	11	-3	-5	3
2	9	-2	-6	-3	-12	-14	9
-6	7	0	-4	-5	-9	-7	1
-7	8	4	-1	11	4	3	-2
3	8	4	-4	2	11	1	1
2	2	5	-1	-6	0	-2	5
-6	-2	2	6	-4	-4	-6	10

Original Lena image

Reconstructed image

Compression rate : .5 bpp

PSNR : 30.91 db

Original Image

Compression ratio-4.2:1

Compression ratio-7.3:1

Original Mandrill image **Reconstructed image**

Compression rate : .22 bpp
Compression ratio : 36:1
PSNR : 19.9 db

THANK YOU