JPEG

JPEG

- Image compression developed by Joint Photographic Experts Group.

- Formally accepted as an international standard in 1992.

JPEG

- Effectiveness of the DCT transform coding method in JPEG relies on three major observations:
  - *Observation 1.* Psychovisual experiments suggest that humans are much less likely to notice the loss of very high-spatial-frequency components than lower-frequency components. Thus, DCT coefficients for the lowest frequencies are most important. As frequency gets higher, it becomes less important to represent the DCT coefficient accurately. It may even be safely set to zero without losing much perceivable image information.

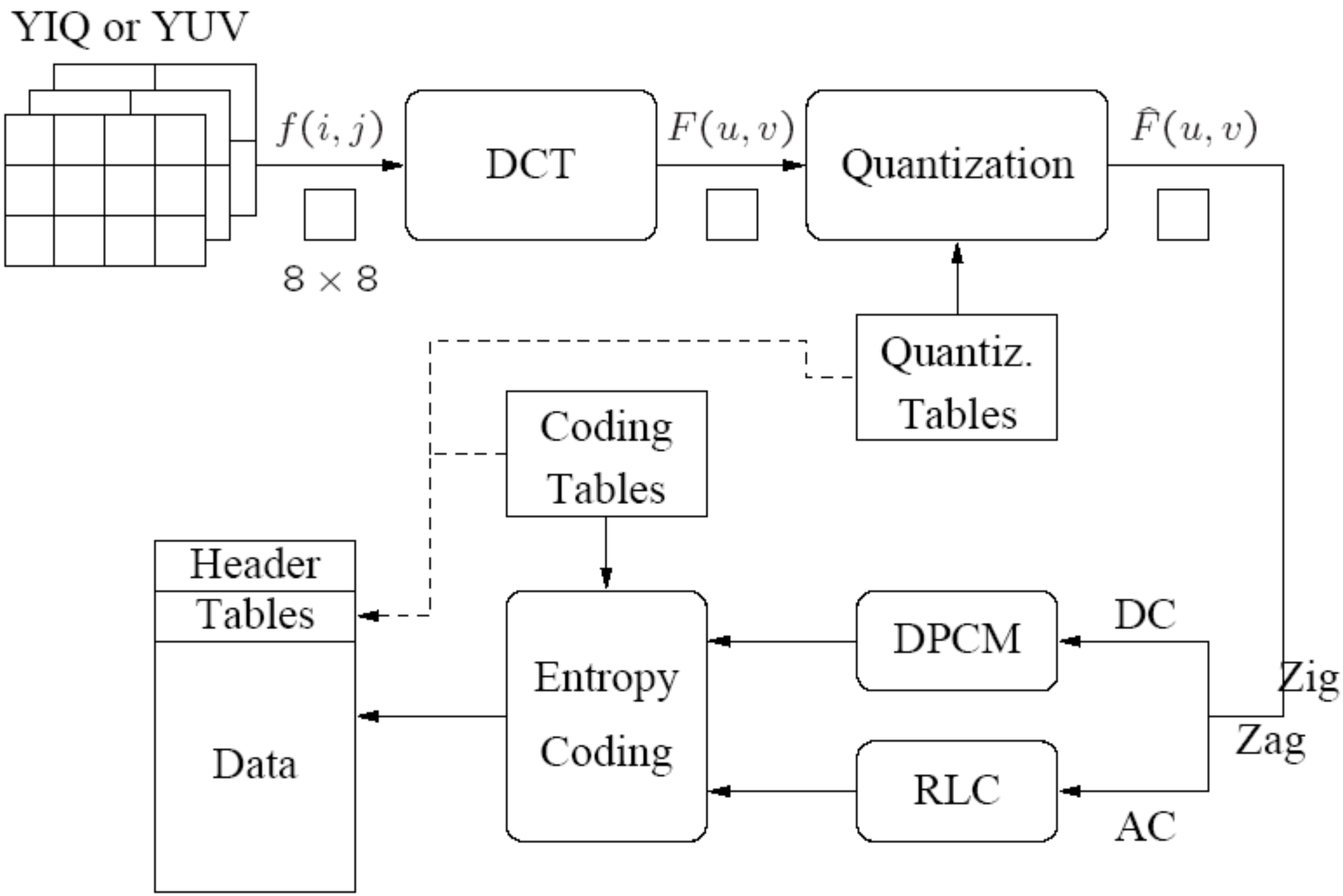
JPEG

- *Observation 2.* Visual acuity (accuracy in distinguishing closely spaced lines) is much greater for gray (black and white) than for colour. We simply cannot see much change in colour if it occurs in close proximity. In view of this, JPEG uses 4:2:0 colour subsampling format. For JPEG decoding, the colour channel has to be enlarged to cover a 2×2 block before viewing.

JPEG

- JPEG encoder consists of the following main steps:
  - Transform RG to YIQ or YUV and subsample colour.
  - Perform DCT on image blocks.
  - Apply quantization.
  - Perform Zigzag scanning and run-length encoding.
  - Perform Entropy coding.

Transform



Block diagram for JPEG encoder

DCT on Image Blocks

- Each image is divided into 8×8 blocks.

- 2D DCT is applied to each block image $f(i,j)$, with output being the DCT coefficients $F(u,v)$ for each block.

- JPEG images look choppy (blocky) when the user specifies a high compression ratio. This is due to the block based (8×8) algorithm used in JPEG.

Quantization

- Quantization step in JPEG is aimed at reducing the total number of bits needed for a compressed image.
- It consists of simply dividing each entry in the frequency space block by an integer, then rounding:

$$\hat{F}(u,v) = round\left(\frac{F(u,v)}{Q(u,v)}\right)$$

where *F(u,v)* represents a DCT coefficient
Q(u,v) is a quantization matrix
$\hat{F}(u,v)$ represents the quantized DCT coefficients

Quantization

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

Luminance 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

Chrominance quantization table

Quantization

- The quantization table is a result from psychophysical studies, with the goal of maximizing the compression ratio while minimizing perceptual loss in JPEG images.

- JPEG compression ratio can be changed by changing the numbers in the $Q(u,v)$ matrix.

Quantization (Example)

An 8 × 8 block from the Y image of 'Lena'

200	202	189	188	189	175	175	175
200	203	198	188	189	182	178	175
203	200	200	195	200	187	185	175
200	200	200	200	197	187	187	187
200	205	200	200	195	188	187	175
200	200	200	200	200	190	187	175
205	200	199	200	191	187	187	175
210	200	200	200	188	185	187	186

$f(i,j)$

515	65	-12	4	1	2	-8	5
-16	3	2	0	0	-11	-2	3
-12	6	11	-1	3	0	1	-2
-8	3	-4	2	-2	-3	-5	-2
0	-2	7	-5	4	0	-1	-4
0	-3	-1	0	4	1	-1	0
3	-2	-3	3	3	-1	-1	3
-2	5	-2	4	-2	2	-3	0

$F(u,v)$

Quantization (Example)

32	6	-1	0	0	0	0	0
-1	0	0	0	0	0	0	0
-1	0	1	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
0	0	0	0	0	0	0	0

$\hat{F}(u,v)$

512	66	-10	0	0	0	0	0
-12	0	0	0	0	0	0	0
-14	0	16	0	0	0	0	0
-14	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	0	0	0

$\tilde{F}(u,v)$

199	196	191	186	182	178	177	176
201	199	196	192	188	183	180	178
203	203	202	200	195	189	183	180
202	203	204	203	198	191	183	179
200	201	202	201	196	189	182	177
200	200	199	197	192	186	181	177
204	202	199	195	190	186	183	181
207	204	200	194	190	187	185	184

$\tilde{f}(i,j)$

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

$\epsilon(i,j) = f(i,j) - \tilde{f}(i,j)$

Quantization

- $\widetilde{F}(u,v)$ denote the de-quantized DCT coefficients, determined by simply multiplying $\hat{F}(u,v)$ by *Q(u,v)* and let $\widetilde{f}(i,j)$ be the reconstructed image block.

- To illustrate the quality of the JPEG compression, especially the loss, the error $\in(i,j) = f(i,j) - \widetilde{f}(i,j)$ is shown.

- Each *Y* value is first reduced by 128 by simply subtracting in order to turn it into zero-mean iamge. The same applies to chrominance signal.