UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BENC 4173 Multimedia Technology & Application

Chapter 3: JPEG Compression

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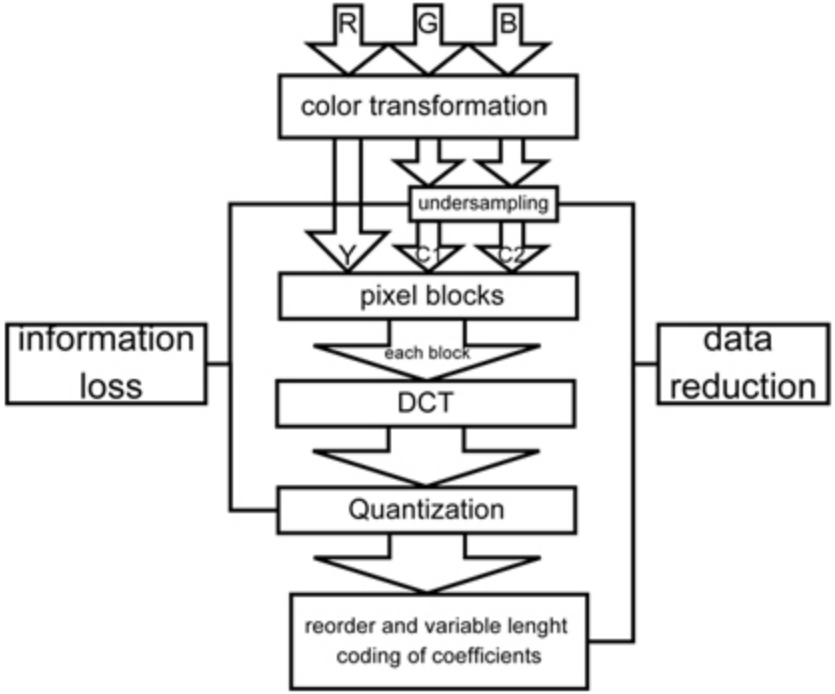
JPEG Compression

- JPEG is not file format.
- JPEG is an acronym for the Joint Photographic Experts Group (standard).
- Referring to the JFIF (JPEG File Interchange Format).
- “Lossy” means, that the compression will also reduce some of the image content (in opposite to lossless compression).

JPEG Compression



Camera Picture

- The camera's sensor is overlaid with a color filter array (CFA), usually a Bayer filter, consisting of a mosaic of a 2x2 matrix of red, green, blue and (again) green filters.
- The green photo-sensors are luminance-sensitive elements.
- The red and blue ones are chrominance-sensitive elements.

JPEG Observation

- **Observation #1**: Human eyes don't see color (chrominance) quite as well as we do brightness (luminance).
- **Observation #2**: Human eyes can't distinguish high frequency changes in image intensity.

STEP 1

- Convert RGB to YCbCr color space
  - Each pixel in your image is stored as a additive combination of Red, Blue and Green (RGB model) values range of 0 to 255.
  - Luminance is more important to the eventual perceptual quality of the image than color.
  - Convert from RGB color space to one where luminance is confined to a single channel. This color space is called YCbCr.

R: 233
G: 30
B: 99

C: 0
M : 0.877
Y : 0.593
K : 0.0471

STEP 1

- Convert RGB to YCbCr color space
  - **Y** is the luminance component and **Cb**, **Cr** are the chrominance components.

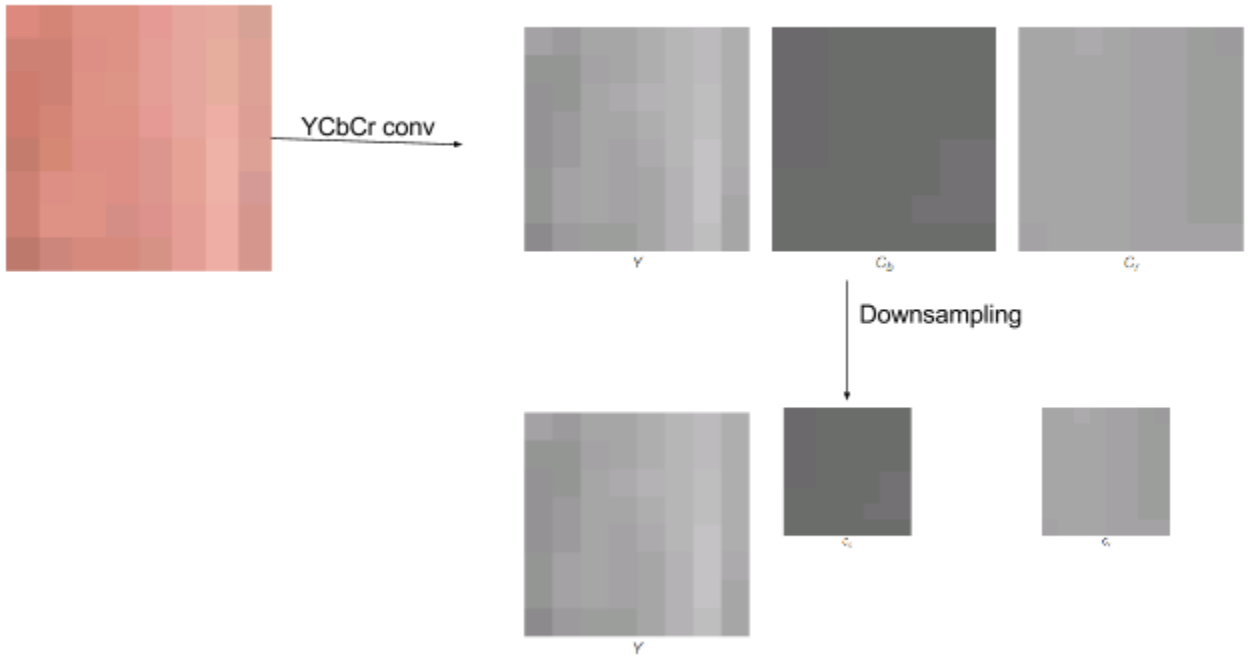
$$Y = 0.299\ R + 0.587\ G + 0.114\ B$$
$$Cb = -0.1687\ R - 0.3313\ G + 0.5\ B + 128$$
$$Cr = 0.5\ R - 0.4187\ G - 0.0813\ B + 128$$

STEP 2

- Downsampling
  - Chrominance is not very important, downsample and reduce the amount of color (CbCr components).
  - Y is sampled at each pixel, where as Cb and Cr are sampled at every block of 2x2 pixels.
  - Now for every 4 Y pixels, there will exist only 1 CbCr pixel.

STEP 2

- Downsampling



STEP 3

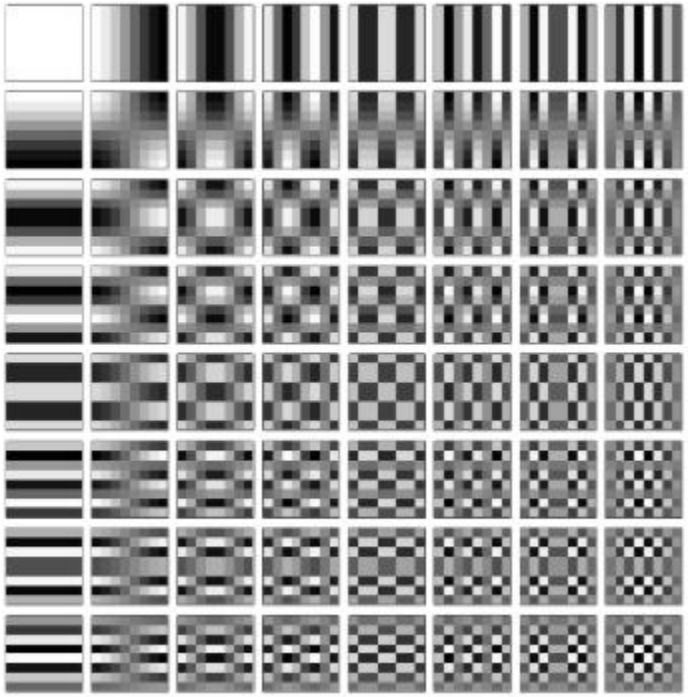
- Discrete Cosine Transform (DCT)
  - Each of the three YCbCr components are compressed and encoded separately.
  - DCT is a method that expresses a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies.

STEP 3

- Discrete Cosine Transform (DCT)
  - These are 64 base images, that are built from cosine functions at different frequencies in the X and Y axes.
  - Convert into frequency domain.

STEP 3

- Discrete Cosine Transform (DCT) – base image



First base image, that is `baseimg[0][0]` will be full white,
for `baseimg[0][1]` to `baseimage[0][7]`, you can see the frequency increasing along the x-axis.
for `baseimg[1][0]` to `baseimage[7][0]`, you can see the frequency increasing along the y-axis.
`baseimg[7][7]` will be totally checkered.

STEP 3

- Discrete Cosine Transform (DCT) – sub-images
  - The entire image is divided into sub-images each of which comprises of 8x8 pixels (each of them as a sub-image).
  - This sub-image can be visualized as an 8x8 matrix.

STEP 3

- Discrete Cosine Transform (DCT) – sub-images

Original Sub-image

64	60	57	56	48	47	47	43
61	58	53	52	48	49	52	53
67	60	53	53	49	47	48	54
68	61	63	63	62	65	65	64
71	61	70	63	69	74	88	88
83	94	102	105	107	111	110	115
95	108	108	124	122	130	128	128
107	118	125	134	137	142	141	137

– Subtract 128 from every value.

STEP 3

- Discrete Cosine Transform (DCT) – sub-images

Shifted sub-image

-64	-68	-71	-72	-80	-81	-81	-85
-67	-70	-75	-76	-80	-79	-76	-75
-61	-68	-75	-75	-79	-81	-80	-74
-60	-67	-65	-65	-66	-63	-63	-64
-57	-67	-58	-65	-59	-54	-40	-40
-45	-36	-26	-23	-21	-17	-18	-13
-33	-20	-20	-4	-6	2	0	0
-21	-10	-3	6	9	14	13	9

– The 8x8 sub-image to be compressed.

– 64 base images.

STEP 3

- Discrete Cosine Transform (DCT) – sub-images

After DCT

-376	-23	1	-2.5	-0.3	4	0.2	-2.6
-224	53	20	3.4	5	3	0.6	2.3
68	3.3	-14	-0.3	-2.8	-1.9	-4.7	-6.2
2.3	-8.9	-1.5	-3.8	-2.5	1.2	1.4	1.9
-8.4	1.2	1.9	3.3	-2.1	5	1.8	5.3
4.5	7.3	-7.4	1.9	1.3	-0.7	-1.5	-6
6.4	6.8	-3.2	-2.6	1.3	-2.1	1.7	1
-16	0.1	9	0.8	1.8	1.7	-1	1

  - Compute DCT for a 2D array.
  - 8x8 table of coefficients, represents the contribution of each base image to the sub-image.

STEP 4

- Quantization
  - Quantize the coefficient table from DCT. (real lossy part of the process).
  - Top-left cells refer to low frequency part, and the bottom-right cells refers to high frequency part.
  - High frequency part can be eliminated without much loss in the look of the image.

STEP 4

- Quantization
  - Every value in the coefficient table is divided by the corresponding value in the quantization table and rounded to the nearest integer using a standard JPEG Quantization table.

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

STEP 4

- Quantization
  - All values except the top-left 3x3 block are all zeroes (high frequency data).
  - JPEG's claim to fame is that with just these 9 values we can get almost the same image back.

After Quantization

-24	-23	0	0	0	0	0	0
-19	4	1	0	0	0	0	0
5	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	0	0	0	0	0	0

STEP 5

- Encoding
  - store the values in a zigzag order: -24, -23, 19, 5, 4, 0, 0, 1, 0, 0, 0, 0, 1 followed by 53 zeros.
  - The final output is JPG encoded using a combination of RLE and Huffman encoding.

After Quantization

-24	-23	0	0	0	0	0	0
-19	4	1	0	0	0	0	0
5	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	0	0	0	0	0	0

STEP 6

- Add Header
  - JPEG Start Of Image (SOI) marker
  - Application markers
  - Width in pixels
  - Height in pixels
  - Number of components (eg 3 for RGB)
- To decompress a JPEG compressed file, simply do the reverse.
- Use Discrete Cosine Transform-III to reverse DCT-II.

Quality Parameter

- The quality parameter that you normally see when exporting JPG images from Photoshop.
- q, is an integer from 1 to 100.
- Clear signs of the blocking stage, as well as the quantization stage.

Quality : 50

Quality : 1

References

- https://arjunsreedharan.org/post/146070390717/jpeg-101-how-does-jpeg-work
- https://www.image-engineering.de/library/technotes/745-how-does-the-jpeg-compression-work
- https://www.freecodecamp.org/news/how-jpg-works-a4dbd2316f35/
- https://cgjennings.ca/articles/jpeg-compression.html try to explore the process of JPEG compression