JPEG Compression

A quick dive into the magic of making images small.

By James Frost

What is JPEG?

- Portable image compression format defined in 1992.

- Common JPEGs are really JFIF

- It was patent free, so could be freely used.

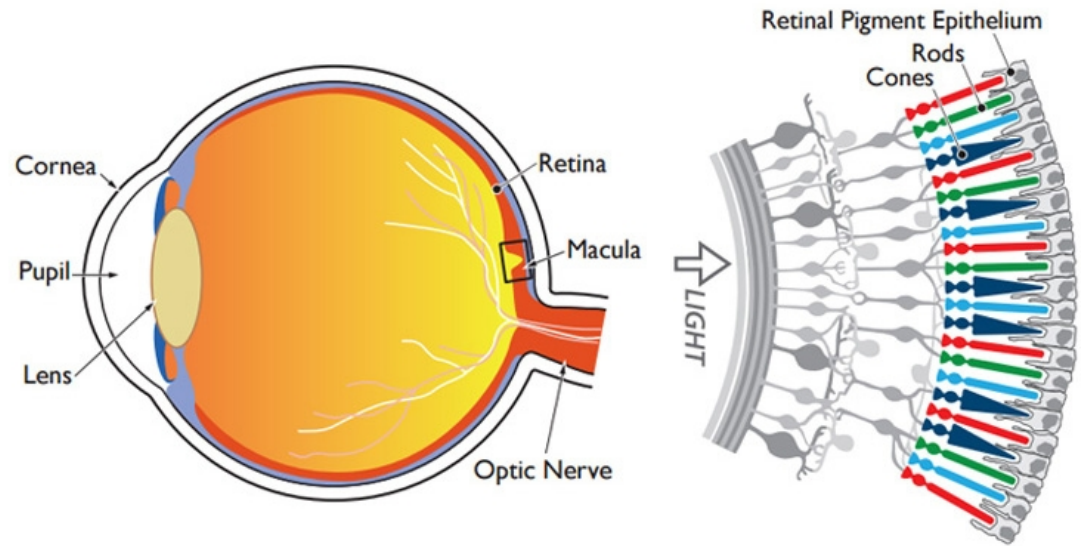- Smaller to send a JPEG + decoder than an uncompressed image.

What is an image

- Images are made up of colour channels.

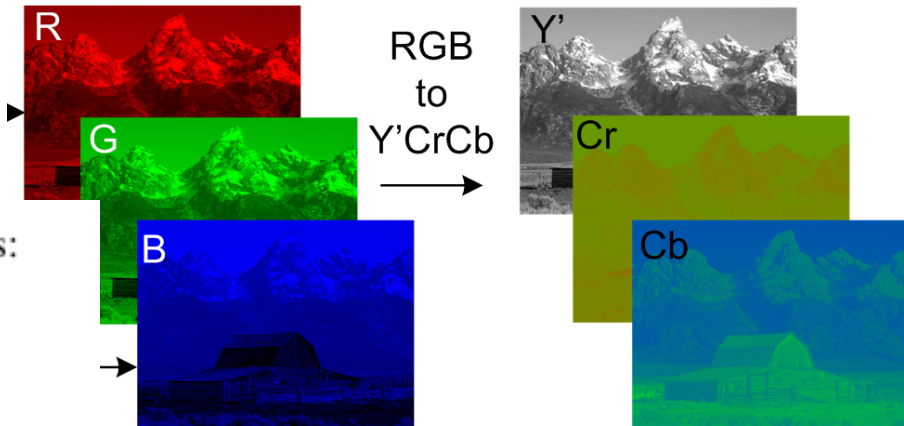- Each channel is just a list of pixel intensity.

How humans see colour

- Much better at seeing brightness than colour.
- Green is most seen colour.

YC$_b$C$_r$ Colour Encoding

- Originally made for colour broadcast in the 1930s

- Y is the brightness

- C$_b$ is the "relative blueness"

- C$_r$ is the "relative redness"

YCbCr (256 levels) can be computed directly from 8-bit RGB as follows:

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

Chroma Sub-sampling

Red

Green

Blue
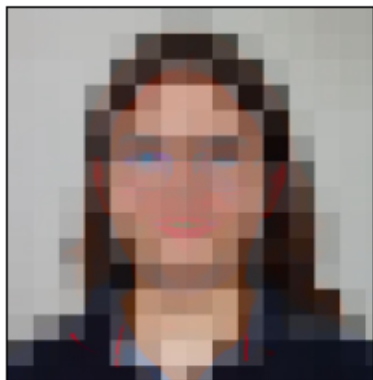
Luminance

Blue Chrominance

Red Chrominance

Discrete Cosine Transform

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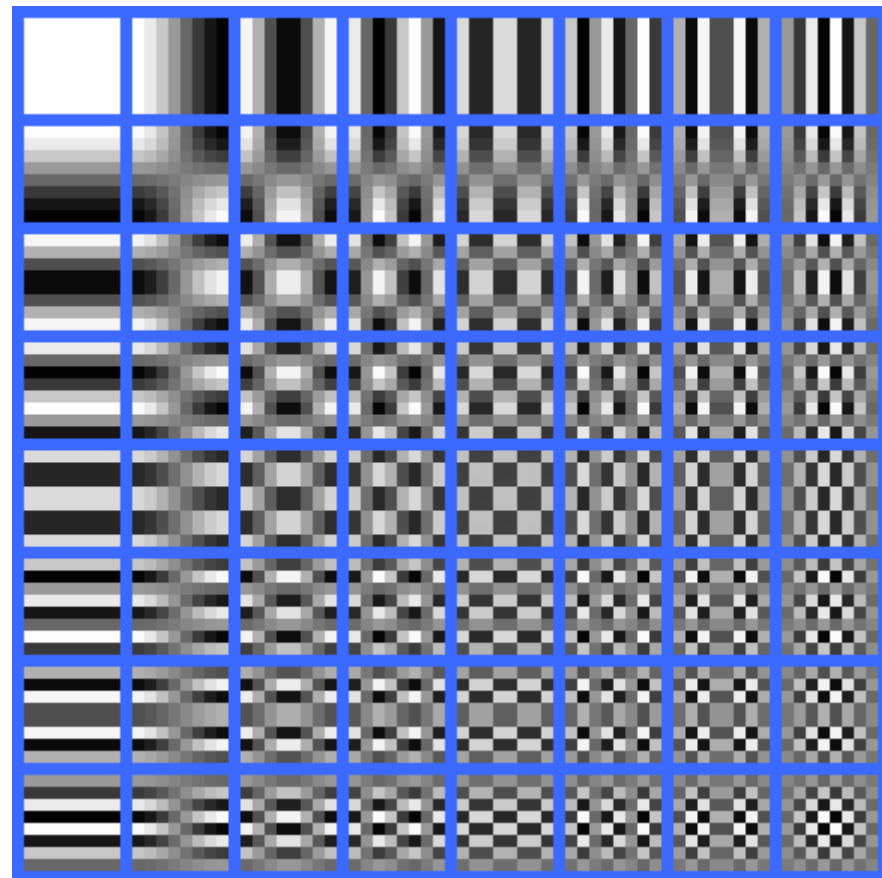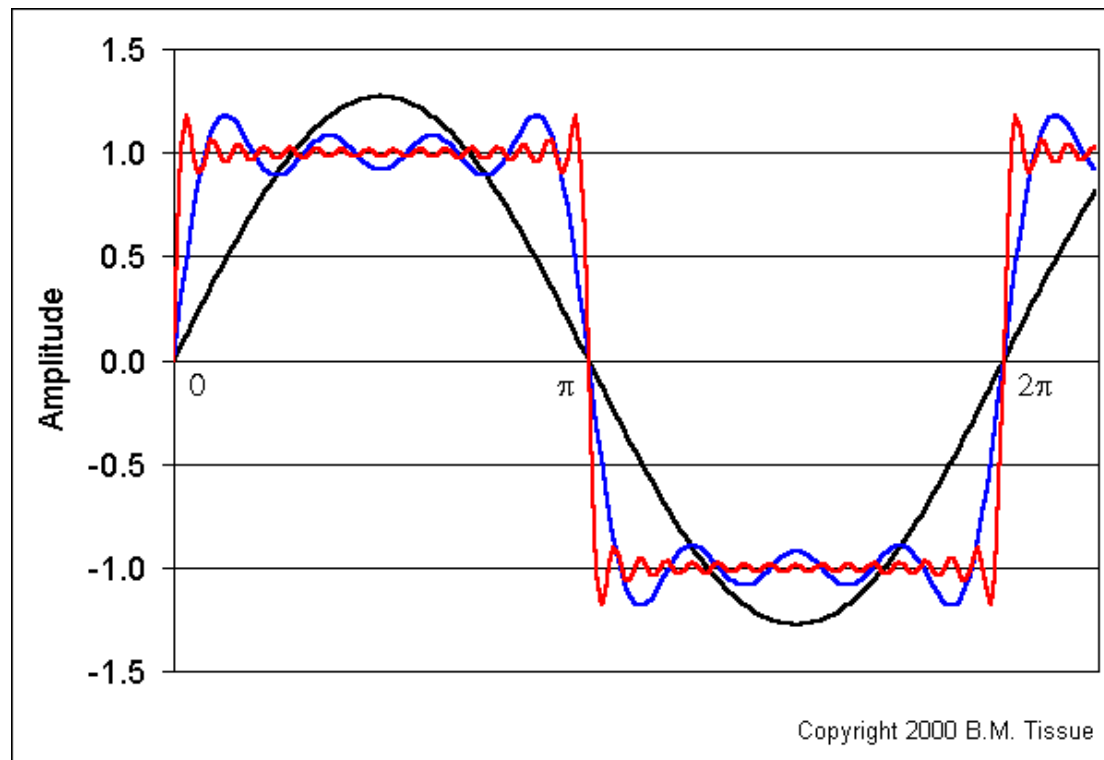
Quantization

1444	-12	-17	13	-22	8	57	-6
-50	29	29	-3	24	-5	-55	6
97	-19	-15	-13	-12	5	-8	8
-93	-3	-12	9	-13	-8	45	-12
58	12	11	-7	17	-1	-42	8
15	-9	0	1	2	5	7	7
-58	13	2	11	-6	-5	29	-13
55	-5	1	-11	10	4	-29	12

X

$$\text{round}\left(\frac{X(u,v)}{Q(u,v)}\right)$$

Q

- Quantize the DCT Coefficients

90	-1	-2	1	-1	0	1	0
-4	2	2	0	1	0	-1	0
6	-1	-1	-1	0	0	0	0
-7	0	-1	0	0	0	1	0
3	1	0	0	0	0	0	0
1	0	0	0	0	0	0	0
-1	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0

Typical JPEG Quantizer

| 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

Encoding

- Quantized DCT Coefficients read in a zig zag pattern.

- Later values will tend to be 0.

- Don't bother storing runs of 0.

- Delta encoding: store difference from last value rather than absolute value.
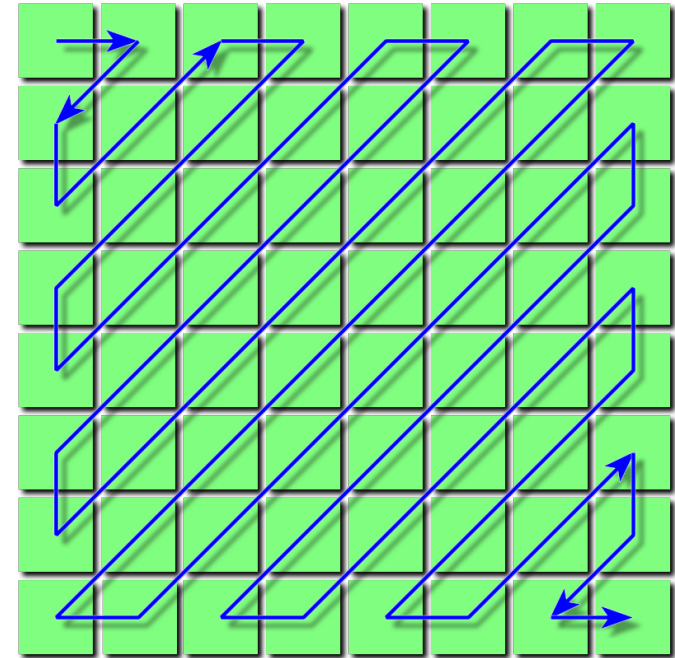
Huffman Encoding

- Lossless compression.

- More common values take fewer branches to reach
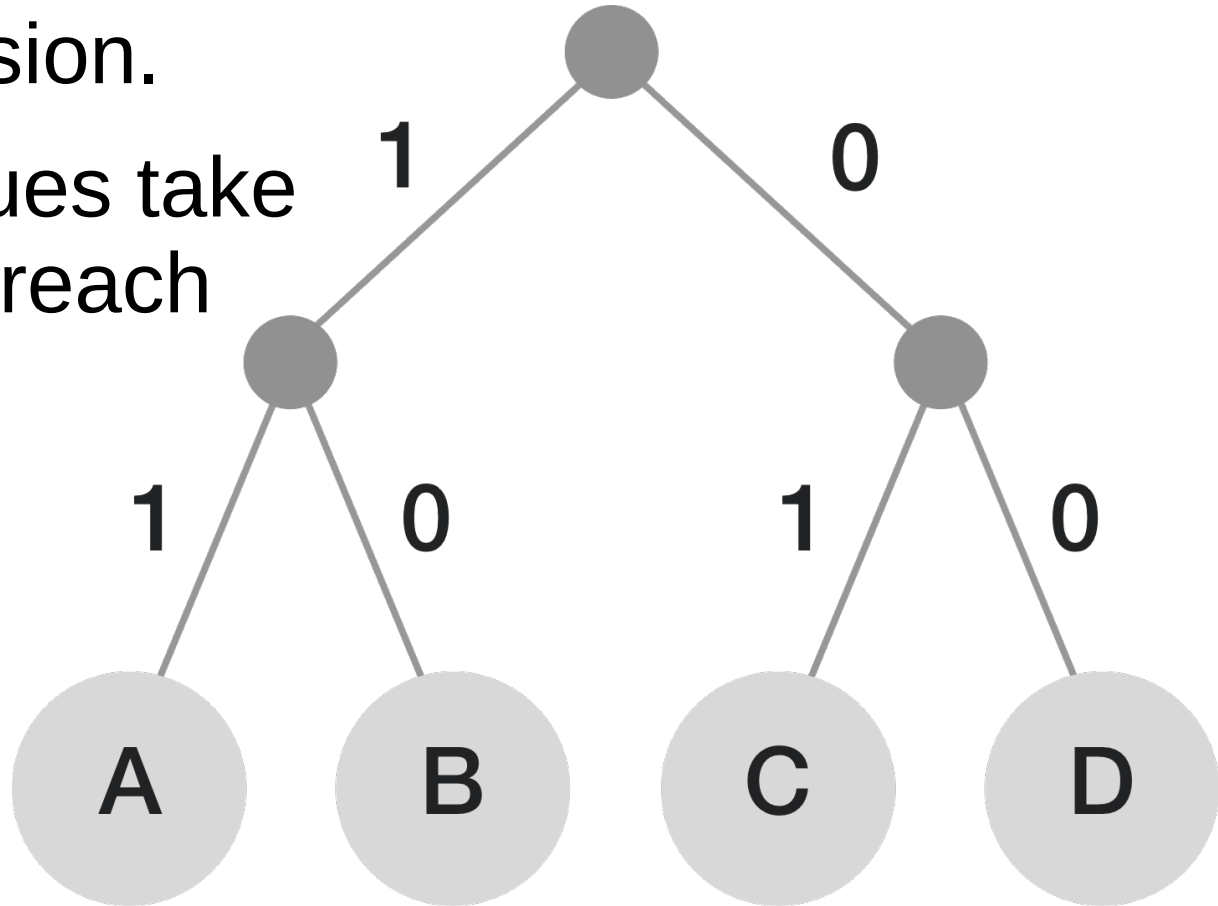
Beyond JPEG?

- AVIF
- JPEG XL
- JPEG is still pretty good for photos

Sources

- Excellent JPEG overview:
https://parametric.press/issue-01/unraveling-the-jpeg/

- Detail on DCT (Computerphile):
https://www.youtube.com/watch?v=Q2aEzeMDHMA

- Huffman Compression (Tom Scott):
https://www.youtube.com/watch?v=JsTptu56GM8

- https://en.wikipedia.org/wiki/JPEG

- JPEG File Interchange Format Version 1.02 Specification

- Many thanks to the people on the JPEG XL discord for clarifications and advice.

Slides at https://www.frost.cx/2021/jpeg-talk.pdf