Image Compression

- GIF (Graphics Interchange Format)
- PNG (Portable Network Graphics)/MNG (Multiple-image Network Graphics)
- JPEG (Joint Pictures Experts Group)

GIF (Graphics Interchange Format)

- Introduced by Compuserve in 1987 (GIF87a), multiple-image in one file/application specific metadata support added in 1989 (GIF89a)
- LZW (Lempel-Ziv-Welch) compression replaced earlier RLE (Run Length Encoding) B&W version
  - Patented by Compuserve/Unisys (has run out in US, will run out in June 2004 in Europe)
- Maximum of 256 colours (from a palette) including a “transparent” colour
- Optional interlacing feature
- http://www.w3.org/Graphics/GIF/spec-gif89a.txt

LZW (Lempel-Ziv-Welch)

- Most of this method was invented and published by Lempel and Ziv in 1978 (LZ78 algorithm)
- A few details and improvements were later given by Welch in 1984 (variable increasing index sizes, efficient dictionary data structure)
- Achieves approx. 50% compression on large English texts
- superseded by DEFLATE and Burrows-Wheeler transform methods

LZW Algorithm

- Dictionary initially contains all possible one byte codes (256 entries)
- Input is taken one byte at a time to find the longest initial string present in the dictionary
- The code for that string is output, then the string is extended with one more input byte, b
- A new entry is added to the table mapping the extended string to the next unused code
- The process repeats, starting from byte b
- The number of bits in an output code, and hence the maximum number of entries in the table is fixed
- once this limit is reached, no more entries are added

PNG (Portable Network Graphics)

- Uses DEFLATE:
  - LZ77 Algorithm with Huffman coding (patent free)
  - Spec: http://www.ietf.org/rfc/rfc1951.txt
- Combines this with prediction:
  - for each image line a filter method is chosen which predicts the colour of each pixel based on the colours of previous pixels and subtracts the predicted colour of the pixel from the actual colour
- Supports up to 48-bit colour
- Data “chunks” can be “critical” or “ancillary”
- Spec: http://www.w3.org/TR/PNG/

LZ77 (Lempel Ziv 1977) Algorithm

- keeps a history window of the most recently seen data and compares the current data being encoded with the data in the history window
- References to the position in the history window, and the length of the match are placed into the compressed stream
- If a match cannot be found the character itself is simply encoded into the stream after being flagged as a literal

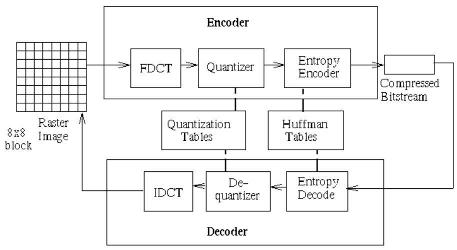
MNG (Multi-image Network Graphics)

- Supports animations
- Version 1.0 of the MNG specification was released in January 2001 (http://www.libpng.org/pub/mng/spec/)
- Structure very similar to PNG
- Differences from PNG:
  - slightly different signature
  - more chunks to support the animation features

JPEG (Joint Photographic Experts Group)

- Used to compress photographic images (gradual changes in colour)
- Not good for computer graphics (sudden changes in colour)
- Can reduce data size 10:1 without visible loss
- Modes: sequential, progressive, hierarchical, lossless
- Uses the JFIF (JPEG File Interchange Format) file format: http://www.w3.org/Graphics/JPEG/jfif3.pdf

JPEG diagram



Block Preparation

- Assume 24-bit RGB input
- Transform into 24-bit YUV (PAL) / YIQ (NTSC)
- Separate Y,U,V matrices
- Chroma subsampling: Square blocks of four pixels are averaged in the U, V matrices (producing YUV4:2:0)
- Element values are re-scaled [-128, 127]
- Image is “tiled”: elements are arranged into 8x8 blocks

FDCT and Quantisation

$$S_{ij} = \tfrac{1}{4} C_j C_i \sum_{x=0}^{7} \sum_{y=0}^{7} P_{xy} \cos[(2x+1)j\pi/16] \cos[(2y+1)i\pi/16]$$

$C_i, C_j = 1/\sqrt{2}$ when $i, j = 0$

$C_i, C_j =$ 1 otherwise

Quantisation: DCT Coefficients are divided by the element in the equivalent position in a quantisation table. The table reduces the high frequency components more. Quantisation table is changed by the user controlled quality parameter.

FDCT example

139	144	149	153	155	155	155	155
144	151	153	156	159	156	156	156
150	155	160	163	158	156	156	156
159	161	162	160	160	159	159	159
159	160	161	162	162	155	155	155
161	161	161	161	160	157	157	157
162	162	161	163	162	157	157	157
162	162	161	161	163	158	158	158

Source Image Samples

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236	-1	-12	-5	2	-2	-3	1
-23	-18	-6	-3	-3	0	0	-1
-11	-9	-2	2	0	-1	-1	0
-7	-2	0	2	1	0	0	0
-1	-1	1	2	0	-1	1	1
2	0	2	0	-1	2	1	-1
-1	0	0	-2	0	2	1	-1
-3	2	-4	-2	2	1	-1	0

Forward DCT coefficients

Quantisation example

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

Quantisation table

→

15	0	-1	0	0	0	0	0
-2	-1	0	0	0	0	0	0
-1	-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	0

Normalised quantised coefficients

Decompressing example

240	0	-10	0	0	0	0	0
-24	-12	0	0	0	0	0	0
-14	-13	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	0

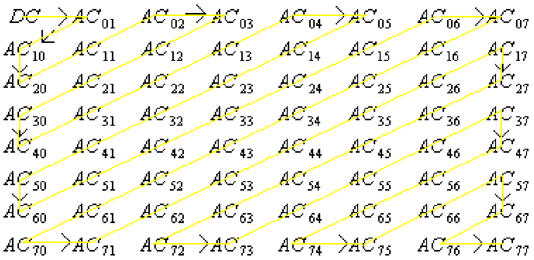
Denormalised quantised coefficients

→

144	146	149	152	154	156	156	156
148	150	152	154	156	156	156	156
155	156	157	158	158	157	156	155
160	161	161	162	161	159	157	155
163	163	164	163	162	160	158	156
163	164	164	164	162	160	158	157
160	161	162	162	162	161	159	158
158	159	161	161	162	161	159	158

Reconstructed Image Samples

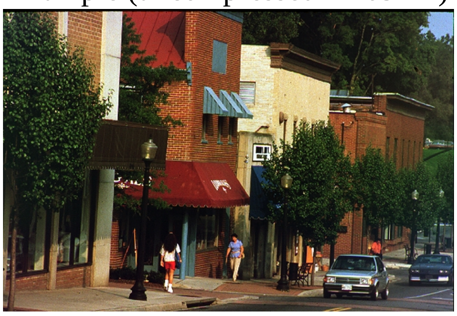
Zig-zag sequencing (linearisation of the 2D matrix)



Entrophy Encoder

- The DC coefficients at (0,0) are encoded by taking the differences from previous values
- The AC coefficients are encoded using run-length encoding (the zig-zag pattern should maximize the runs of 0s)
- Huffman coding assigns shorter codes to more frequent numbers

Example (uncompressed – 763KB)



Example (5% quality – 9KB)

JPEG references

- "Digital Compression and Coding of Continuous-tone Still Images, Part 1, Requirements and Guidelines." ISO/IEC JTC1 Draft International Standard 10918-1, Nov. 1991.
- "Digital Compression and Coding of Continuous-tone Still Images, Part 2, Compliance Testing." ISO/IEC JTC1 Committee Draft 10918-2, Dec. 1991.
- http://www.wotsit.org/search.asp?page=5&s=graphics
- Wallace, Gregory K. "The JPEG Still Picture Compression Standard", Communications of the ACM, April 1991 (vol. 34 no. 4), pp. 30-44.
- "JPEG Still Image Data Compression Standard" William B. Pennebaker, Joan L. Mitchell, Van Nostrand Reinhold, 1993, ISBN 0-442-01272-1