Image Compression

What is an Image File Format?

- Image file formats are standard way of organizing and storing of image files.
- Image files are composed of either pixels or vector (geometric) data.
- The pixels that compose an image are ordered as a grid (columns and rows)
- Each pixel consists of numbers representing levels of brightness and color.

Image File Size

- This is expressed as number of bytes
- This value depends on two factors
  - Resolution (Number of pixels on the screen)
  - Bit depth (Number of bits allocated for a pixel)
- Large number of rows and columns increase the resolution and it leads to larger the file size.

Image Compression

- Compression is a term used to describe ways of cutting the size of the file.
- Image files typically are larger than text files.
- Web pages often contain many images that are transmitted across slow connections
- A larger file type means more disk usage and slower downloads

Therefore it is helpful to have a way to represent images in a compact format.

Types of Image File Compression

- There are two types of Compression algorithms.

  Lossless Compression

  Lossy Compression

Lossless Compression

- Algorithms reduce file size without losing image quality
- They are not compressed into as small a file as a lossy compression file.
- When image quality is valued than file size, lossless algorithms are typically chosen.
  - because it lets you recreate the original file exactly.
- All lossless compression is based on the idea of breaking a file into a "smaller" form for transmission or storage and then putting it back together on the other end so it can be used again.

Lossy compression

- This algorithms consider the limitations of the human eye and discard invisible information.
- Most lossy compression algorithms allow for variable quality levels (compression)
- At the highest compression levels, image weakening becomes noticeable
- **Lossy compression** works very differently.
- These programs eliminate "unnecessary" bits of information, so that it is smaller.
- This type of compression is commonly used for reducing the file size of bitmap pictures

Some General Concepts

- **Bit Rate and Compression Ratio**
  - Bit rate: bits/pixel, sometimes written as bpp
  - Compression ratio (CR):

$$CR = \frac{\text{number of bits to represent the original image}}{\text{number of bits in compressed bit stream}}$$

Compression Algorithms

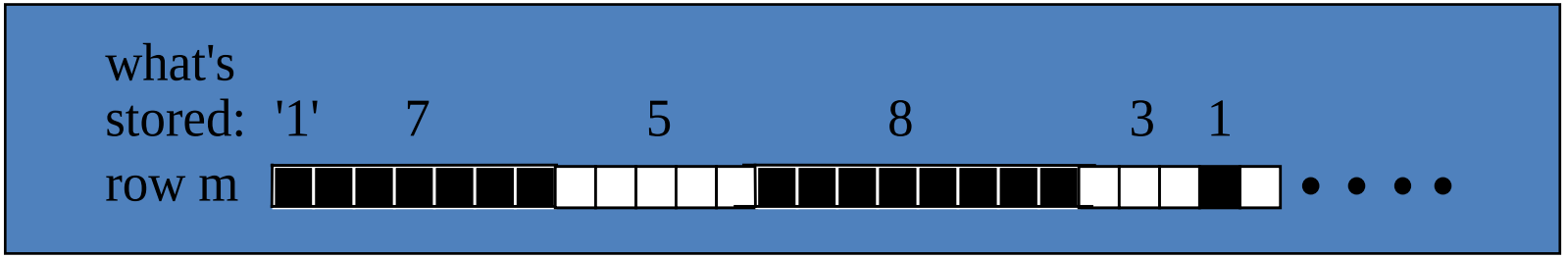
	Algorithm	Basic Concept	Comp Ratio	File Format
Loss-Less	RLE (Run-Length Encoding)	Compress repetitive data	~1.2	BMP
	LZW (Lempel-Ziv-Welch)	Build treed dictionary	~2.0	TIFF, GIF
Lossy	DCT (Discrete Cosine Transformation	Transform to series of Cosine functions	~100	JPEG, MPEG1/2
	Colour Space Compression	Cut non-sensitive color information	~2	JPEG, (TV)
	Wavelet	Transform to series of Wavelet functions	~100	JPEG2000, MPEG4

Run Length Encoding (RLE)

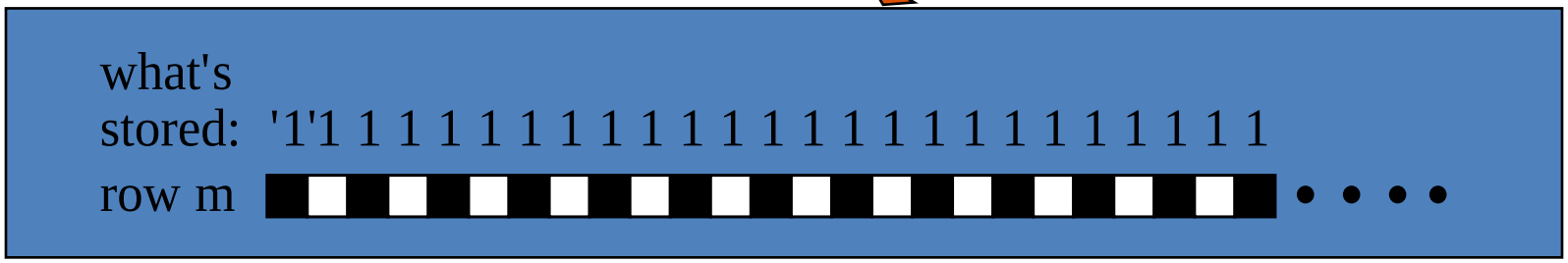
- Many files, particularly image files, contains sequences of identical symbols.
  - Eg. In an image, a section of many adjacent pixels may all be the same color .
  - Be encoded with the same bit pattern.
- RLE replaces sequence of identical bit patterns with
  - one instance of the pattern, and
  - a number specifying how many times the pattern is to be repeated.
- Uses with BMP

Run Length Encoding

- **Run Length**
  - The length of consecutively identical symbols
- **Run length encoding Example**



- **When Does it Work?**
  - Images containing many runs of 1's and 0's
- **When Does it Not Work?**



Run Length Encoding

- **Decoding Example**

  A binary image is encoded using run length code row by row, with “0” represents white, and “1” represents black. The code is given by

Row 1: “0”, 16
Row 2: “0”, 16
Row 3: “0”, 7, 2, 7
Row 4: “0”, 4, 8, 4
Row 5: “0”, 3, 2, 6, 3, 2
Row 6: “0”, 2, 2, 8, 2, 2
Row 7: “0”, 2, 1, 10, 1, 2
Row 8: “1”, 3, 10, 3
Row 9: “1”, 3, 10, 3
Row 10: “0”, 2, 1, 10, 1, 2
Row 11: “0”, 2, 2, 8, 2, 2
Row 12: “0”, 3, 2, 6, 3, 2
Row 13: “0”, 4, 8, 4
Row 14: “0”, 7, 2, 7
Row 15: “0”, 16
Row 16: “0”, 16

decode →

Decode the image

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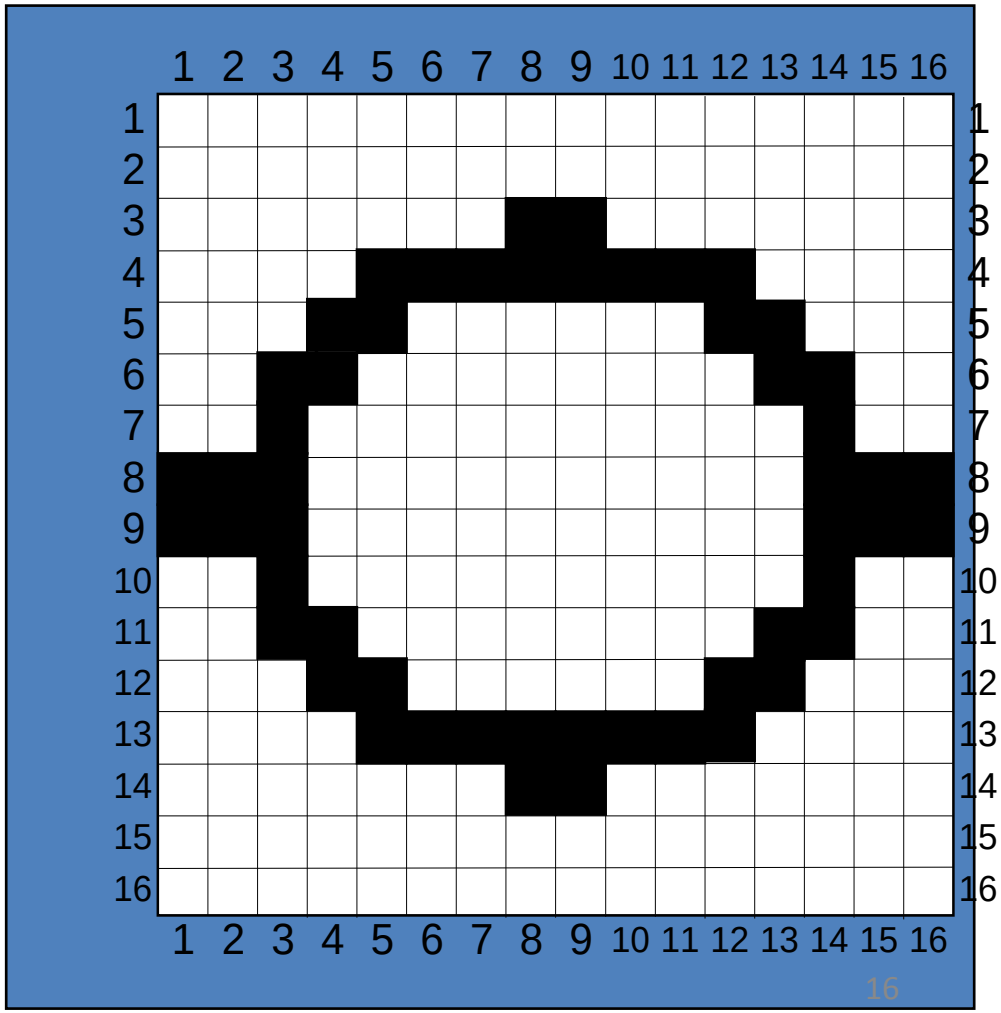
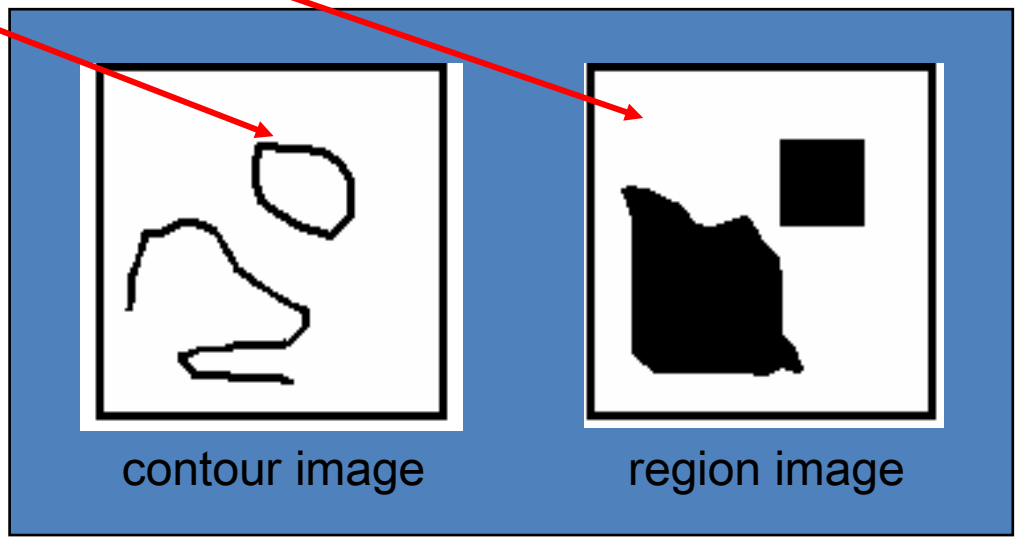
Row 9: “1”, 3, 10, 3
Row 10: “0”, 2, 1, 10, 1, 2
Row 11: “0”, 2, 2, 8, 2, 2
Row 12: “0”, 3, 2, 6, 3, 2
Row 13: “0”, 4, 8, 4
Row 14: “0”, 7, 2, 7
Row 15: “0”, 16
Row 16: “0”, 16

decode →



Chain Coding

Assume the image contains only single-pixel-wide contours, like this, not this



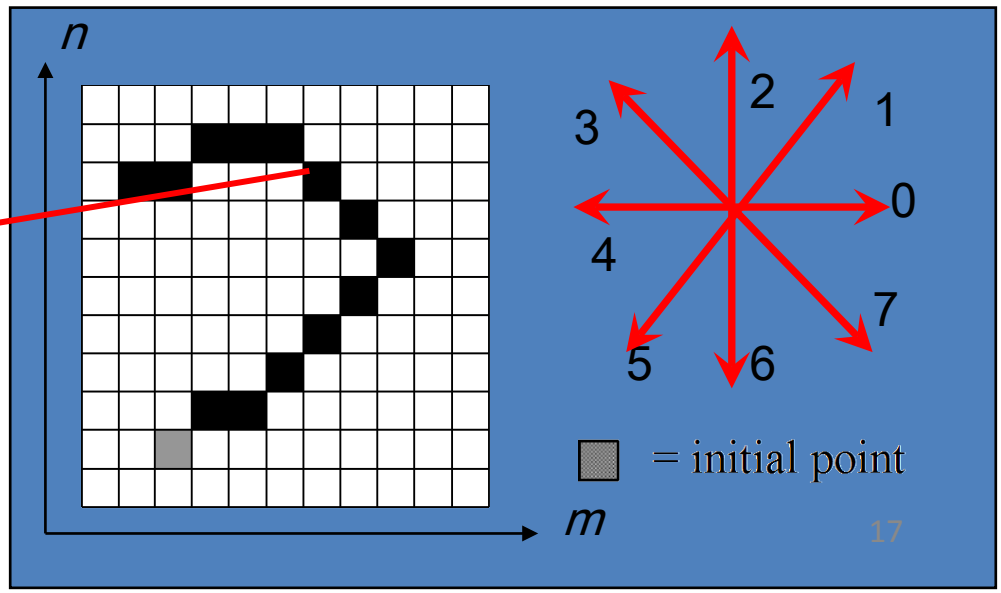
After the initial point position, code direction only

Code Stream:

(3, 2), 1, 0, 1, 1, 1, 1, 3, 3, 3, 4, 4, 5, 4

initial point position

chain code



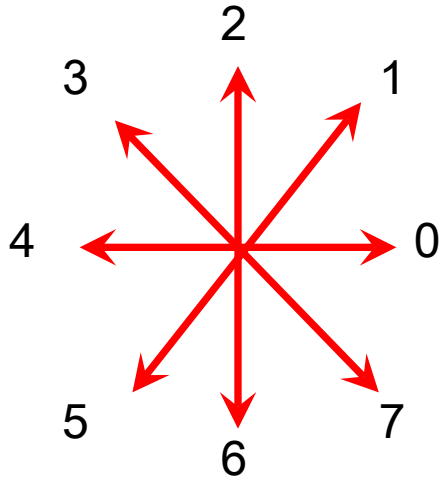
Chain Coding

- **Decoding Example**

The chain code for a 8x8 binary image is given by:

(1, 3), 7, 7, 0, 1, 1, 3, 3, 3, 1, 1, 0, 7, 7

decode



Decode the image

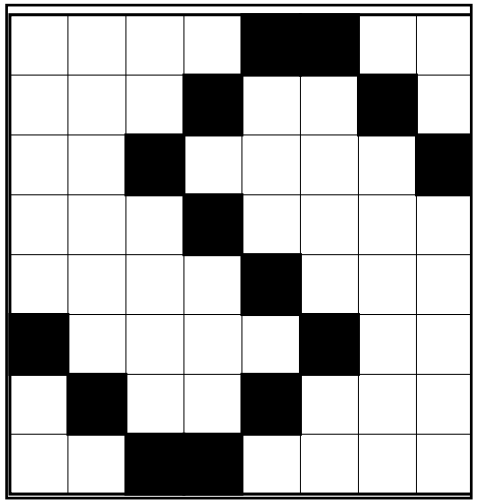
Chain Coding

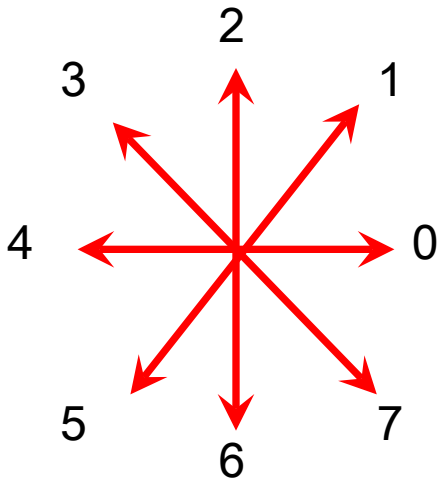
- **Decoding Example**

The chain code for a 8x8 binary image is given by:

(1, 3), 7, 7, 0, 1, 1, 3, 3, 3, 1, 1, 0, 7, 7

decode





Variable Word Length Coding

Assign **short words** to gray levels that occur **frequently**
Assign **long words** to gray levels that occur **infrequently**

Example: A 4x4 4bits/pixel original image is given by

2	8	6	6
6			8
8			10
9			14

Default Code Book

0:	0000
1:	0001
2:	0010
3:	0011
4:	0100
5:	0101
6:	0110
7:	0111
8:	1000
9:	1001
10:	1010
11:	1011
12:	1100
13:	1101
14:	1110
15:	1111

encode

Bit rate = 4bits/pixel

Total # of bits used to represent the image:

4x16 = 64 bits

0010	1000	0110	0110
0110	1000	1000	1000
1000	1000	1010	1010
1001	1010	1010	1110

Variable Word Length Coding: Example

- Encode the original image with a **CODE BOOK** given left

Huffman Code Book

2	8	6	6
6	8	8	8
8	8	10	10
9	10	10	14

6: 01
7: 0000101
8: 10
9: 00100

0001	10	01	01
01	10	10	10
10	10	11	11
00100	11	11	0011

encode

Total # of bits used to represent the image:

4+2+2+2+2+2+2+2+2+
2+2+2+5+2+2+4
= 39 bits

Bit rate = 39/16

= 2.4375 bits/pixel

CR = 64/39 = 1.6410

Lempel-Ziv-Welch (LZW)

- Dictionary based coding algorithm
- Another Loss-Less compression algorithm.
- It was not designed specifically for graphics
- Data Dictionary is used to represent linear sequences of data in a uncompressed input stream.

  Then uses an algorithm similar to RLE.
- It does not work well with black and white images.
- Uses with GIF

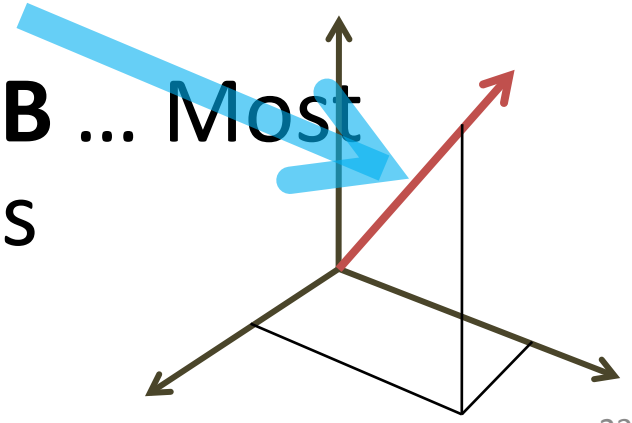
Color Space Compression

- Uses human eye characteristics
  - Less sensitive to color than lightness
  - Less sensitive to **Red** **than** **Green**
- YUV color space
  - Originally developed for color TV signal
  - Convert color to Luminance(Y) and
- Chrominance (U,V) values

Y=0.299 R + 0.587 G + 0.114 B … Most sensitive color for human eyes

U=(B-Y)

V=(R-Y)



Color Space Compression cont…

- Reduce color information
  - Y:U:V = 4:2:2 (TV)
  - Y:U:V = 4:1:1 (JPEG)
  - Y:U:V = 4:1:0 (JPEG)

Mathematical Transformation

- **Convert images to mathematical functions**
  - **Discrete Cosine Transformation (DCT)**
    - Use series of cosine functions to approximate image.
    - Use with JPEG, MPEG 1/2
  - **Wavelet Transformation**
    - Use wavelet function to approximate image.
    - Use with JPEG2000, MPEG 4

Both are **Lossy Compression Algorithms**

DCT vs Wavelet Algorithm Comparison

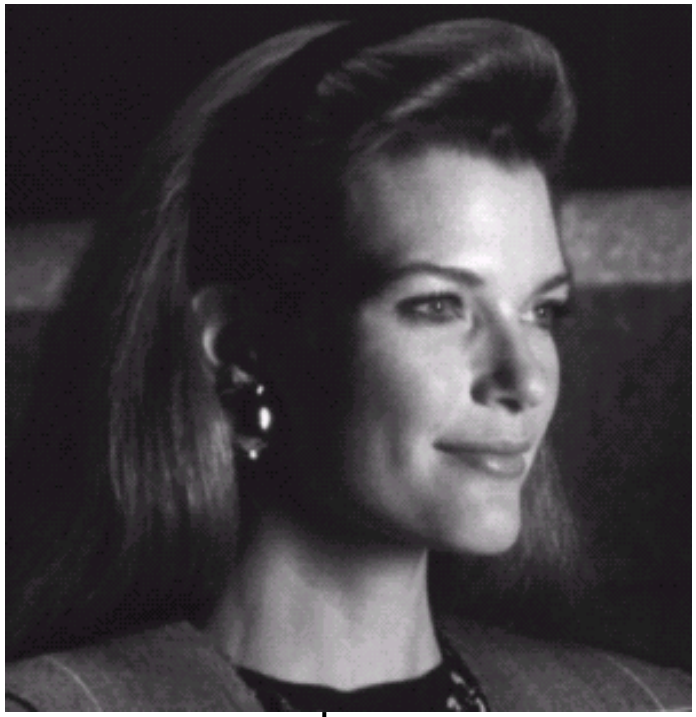
Original Image
(154KB)

Compress to 3 KB (1:50)

DCT

Wavelet

Image Compression: Coding and Decoding

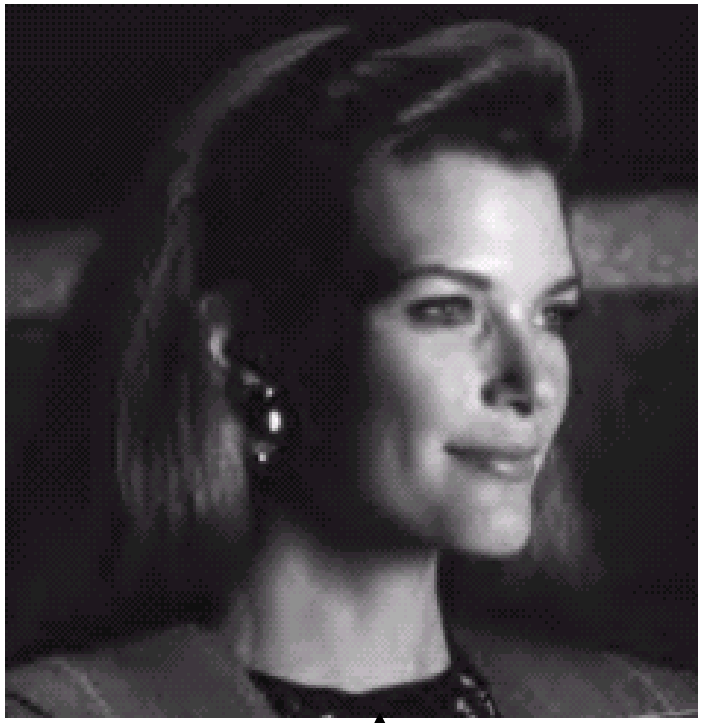


original image 262144 Bytes

image encoder

compressed bitstream
0011100001001101…
(2428 Bytes)

image decoder



compression ratio (CR) = 108:1

Image File Formats

BMP – Bitmap File Format

- Use only for bitmap graphics in windows platform only.
- Compression of bitmap files is not supported, since very large file size.
- The main advantage is their wide acceptance, simplicity and use in windows programs.
- Use “.bmp” extension at the end.

BMP – Bitmap File Format

Uses:

- Used for Microsoft's Paint program.
- Suitable for background images and wallpapers.
- This is especially true for screen shots.
- Images from scanners are usually stored in BMP files.

JPEG - Joint Photographic Experts Group

- One of the most popular format for web graphics.
- Use lossy data compression technique.
- Support for 24-bit color information.
- Produce relativly small file sizes.
- When saving use “.jpg” extension. At the end.

JPEG - Joint Photographic Experts Group

- JPEG uses a mathematical formula based on the way eyes perceive color.
- JPEG compression algorithm looks at a pixel and its neighbors in all directions and finds the factors for that formula which will best represent all those pixels.
- Rather than storing the pixels, it compresses the image by storing only the factors to save space.
- When view the image again, the JPEG

JPEG - Joint Photographic Experts Group

Uses:

- Most common in photographs and continuous-tone bitmap images.
- All digital cameras have this option.
- Used as the image compression algorithm in many Adobe PDF files.
- Ideal for web pages and e-mailing of photos.

GIF – Graphics Interchange Format

- One of the most popular file formats for web graphics and for exchanging graphics files between computers.
- Support for 8-bit of color information or less.
- This makes GIF format suitable for storing graphics with relatively few colors such as simple diagrams, shapes and cartoon style images.
- Use lossy file compression.
- Because of this, it is effective when large

GIF – Graphics Interchange Format

Uses:

- Supports for animation and is still widely used to provide image animation effects.
- Use for web graphics and exchanging graphic files between computers.

PNG – Portable Network Graphics

- Similar to GIF.
- Lossless data compression technique.
- PNG supports for true color, where GIF supports only for 256 colors.
- Platform independent.
- Should be used for single image, not for animation.
- Use “.png” extension.

PNG – Portable Network Graphics

Uses:

- The lossless PNG format is best suited for editing images.

TIFF – Tag Interchange File Format

- Tag based format and used for bitmap images.
- Platform independent.
- Compatible with wide range of software applications.
- This format is complex, so files larger than GIF or JPEG.
- Support for lossless compression.

TIFF – Tag Interchange File Format

Uses:

- Widely accept as a photograph file standard in the printing industry

EPS – Encapsulated Postscript

- Is a meta file format.
- Can use for vector images or bitmap images.
- Can be used in various of platforms.
- This format contains postscript information and should be used when printing to a postscript output device.
- Use “.eps” extension.

PICT – Picture File Format

- Use for primarily on Machintosh platform.
- Most commonly used for bitmap images.
- Lossless format.
- Therefore files are very large.
- Use “.pct” extension.

Uses:

- Use in video editing, animation, desktop computer presentations and multimedia authoring.