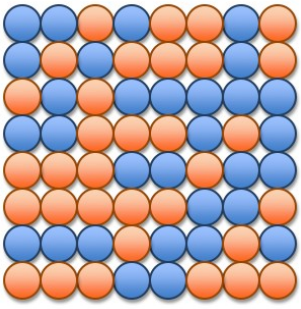
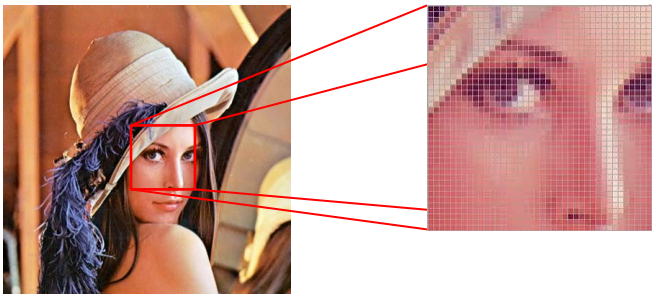


UNIT 7C

Data Representation: Images and Sound

Pixels

- An image is stored in a computer as a sequence of *pixels*, picture elements.

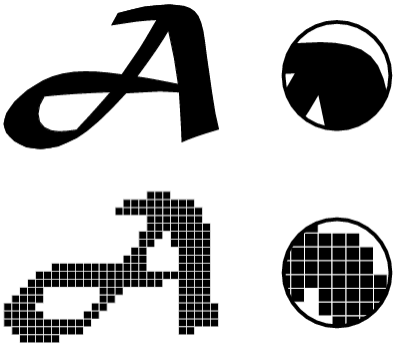


Resolution

- The resolution of an image is the number of pixels used to represent the image (e.g. 1024 X 768).
- Each pixel represents the average color in that region.
- The higher the resolution, the more accurate the image will appear.

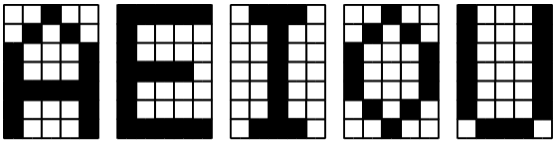
Vector vs. Bitmap

- There are two major ways to store images:
  - Vector graphics: a series of lines or curves. Expensive to compute but smoothly rescales.
  - Bitmap graphics: an array of pixels. Cheap to compute, but scales poorly.



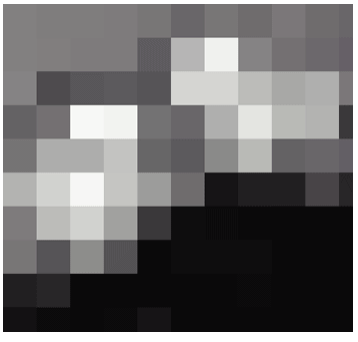
Storing Bitmap Images

- In bitmapped images, each pixel is represented in computer memory in binary, just like other data types.
- If pixels of an image are black or white only, then we only need 1 bit per pixel to store the image.



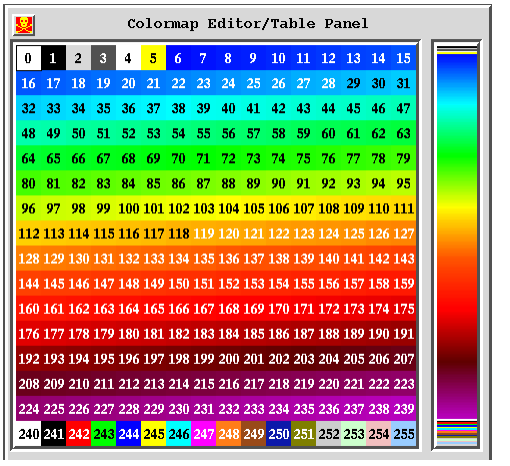
Grayscale Images

- Grayscale images contain pixels that are various shades of gray, from black (maximum gray) to white (minimum gray).
- If there are 256 levels of gray for pixels, we can represent each pixel using 8 bits.
  11111111 = white
  : (shades of gray)
  00000000 = black



256-color images (8-bit color)

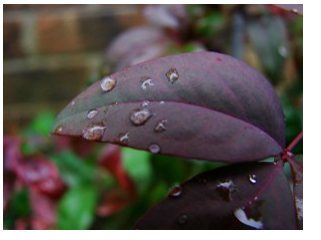
- Each pixel is represented with a 8-bit value that is an index into a *palette* of 256 colors.



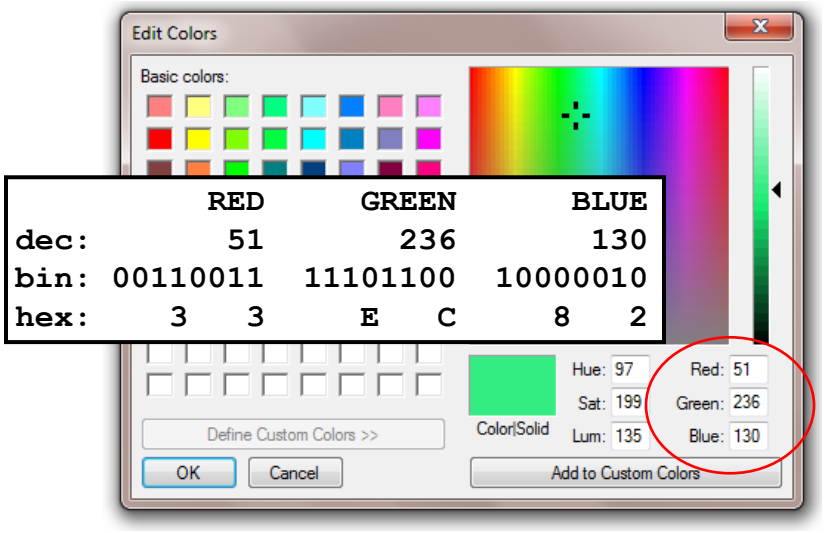
RGB-color images (24-bit color)

- Colors are represented as mixtures of red (R), green (G), and blue (B).
- Each pixel is represented using three 8-bit values, one for each color component.
- This representation allows for 2^{24} = 16,777,216 different colors.
- This representation is also called “true color”.

(image from Wikipedia)



RGB example

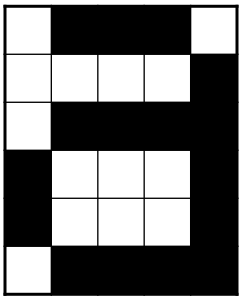


Comparing Representations

- If an image has a resolution of 640 X 480 (307,200 pixels), how many bytes does each representation require?
  - B&W 38,400 bytes
  - 8-bit grayscale 307,200 bytes
  - 256-color (8-bit color) 307,200 bytes
  - True color (RGB) 921,600 bytes
- A single RGB screen image of size 1600 X 1200 requires over 5.76 million bytes!

RLE compression

- Run-Length Encoding is a lossless compression technique used in early image files.
- Instead of storing the 8-bit value for every pixel, we store an 8-bit value along with how many of these occur in a row (run).
- This saves a lot when there are large runs of the same color.

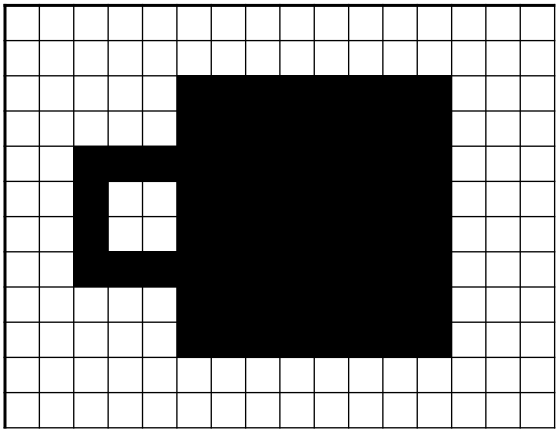


Color, Run, Color, Run, ...

255,1,0,3,255,1
255,4,0,1
255,1,0,4
0,1,255,3,0,1
0,1,255,3,0,1
255,1,0,4

(Colors: 0=Black, 255=White)

Comparison



RLE	Bitmap
2 bytes	16 bytes
2 bytes	16 bytes
6 bytes	16 bytes
6 bytes	16 bytes
6 bytes	16 bytes
10 bytes	16 bytes
10 bytes	16 bytes
6 bytes	16 bytes
6 bytes	16 bytes
6 bytes	16 bytes
2 bytes	16 bytes
2 bytes	16 bytes
64 bytes	192 bytes

GIF: Graphic Interchange Format

- Developed by CompuServe in the late 1980s to represent 8-bit images efficiently.
- Each pixel is an 8-bit value, mapping to a table of 256 24-bit RGB colors.
- A *codebook* stores recurring sequences.
- Useful for representing images with fewer colors or large areas of color like company logos.

GIF Patent Issues

- GIF uses the LZW (Lempel-Ziv-Welch) compression algorithm, which produces variable-length codes for common sequences of pixels.
- The LZW algorithm was patented by Sperry Corp., later Unisys Corp. Compuserve didn't know this when they created GIF.
- Later, Unisys tried to charge license fees for use of the LZW algorithm in software products.
- Some outraged users launched a GIF boycott.
- The patent expired in 2003.

JPEG (JPG): Joint Photographic Experts Group

- A lossy compression technique used generally for photographic images.
  - Uses a variant of Huffman encoding.
- Supports varying levels of compression.

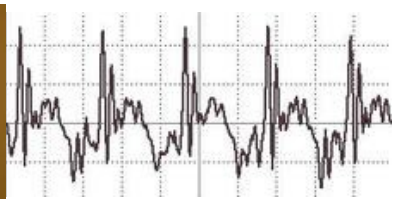
Higher quality
Compression 2.6:1
(images from Wikipedia)

Medium quality
Compression 23:1

Lowest quality
Compression 144:1

Sound

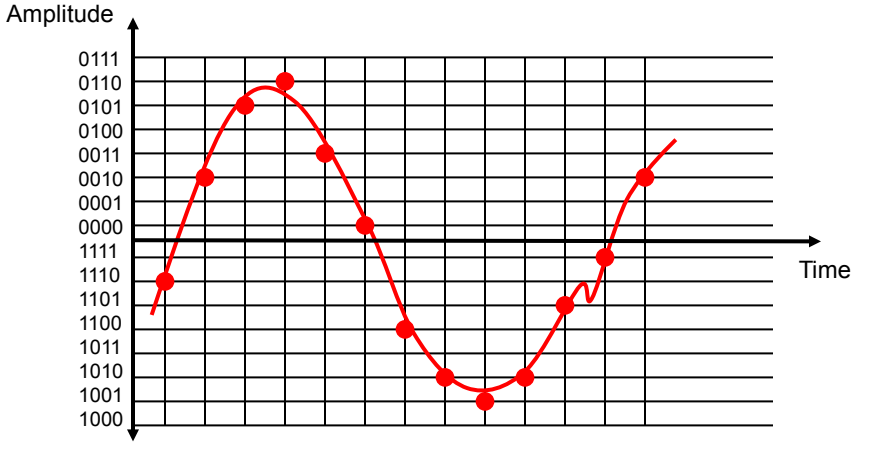
- When an instrument is played or a voice speaks, changes occur in air pressure which our ears interpret as sound.



Sampling

- A sound is represented digitally by sampling an electronic version of the audio signal.
- The amplitude of the signal is measured (sampled) at equally-spaced time intervals.
- The amplitude axis is divided into equally-spaced intervals depending on how many bits we want to store per sample.

Sampling



1110 0010 0101 0110 0011 0000 1100 1010 1001 1010 1101 1111 0010 ....

Sampling

- In order to reproduce the audio waveform as accurately as possible, we need to increase the sampling rate (samples per second) and the number of amplitude levels (bits per sample).
- Note in the previous picture how some of the samples had to be moved up or down to match an amplitude level and some finer changes in the sound signal could be missed if the sampling rate is too low.

Sampling

- Digital recordings are typically sampled at 44,100 samples per second (Hertz – Hz).
  - This is due to the "sampling theorem" that states that the sampling rate must be at least twice the highest frequency in the sound, and humans can hear up to approx. 20,000 Hz.
- For accurate amplitude readings, sound is often sampled at 16-bits per sample (so there are 65,536 amplitude levels that can be measured).
  - Some systems sample at finer amplitude levels (e.g. 24 bits per sample)

MP3

- MP3 (MPEG3) is a lossy compression technique.
- This format takes advantage of some facts about human hearing.
  - We can't hear certain sounds (very low or very high frequencies).
  - Our hearing is better in mid range frequencies than on the low and high ends.
  - If a loud and soft sound play at the same time, we can't hear the soft sound.
- MP3 filters the audio signal based on these properties.

MP3 Compression

- Like JPEG, MP3 has various levels of compression:

Bit Rate	Compression Ratio	Comments
256Kbps	5:1	Supreme (near best)
192Kbps	7:1	Excellent (better)
128Kbps	11:1	CD quality (good)
96Kbps	19:1	Near CD quality (fair)
64Kbps	22:1	FM quality (poor)

- MP3 also has Variable Bit Rate (VBR) since compression ability can vary at different segments of the digital recording.

MP4

- MPEG = Moving Picture Experts Group
- MP4 (MPEG4) is a compression technique developed for video.
- Since most of the time there are only small changes from one frame of a video to the next frame, large savings are possible.
- DVD movies and smart phones use the MP4 encoding.

YouTube, Vimeo, etc.

- Video hosting sites such as YouTube and Vimeo support a variety of formats, including MP4, AVI (Microsoft), QuickTime (Apple), and Flash (Adobe).
- You can download videos from these sites in your preferred format using tools such as KeepVid (visit www.keepvid.com).
- Uploading and then downloading a video may reduce the quality due to lossy compression.