

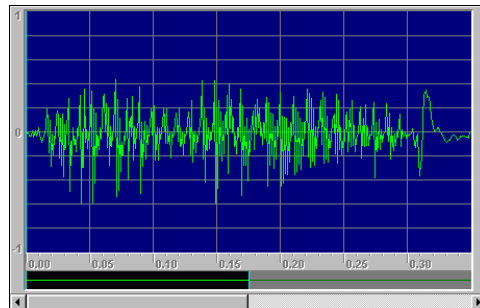
Data Manipulation

-Representation, Compression, and
Communication Errors

Audio and Image Representation

- Why should the (wireless) broadcasting channels be RE-LICENSED, and DIGITALIZED?
 - Limited bandwidth (頻寬)
 - Better technology
 - => less bandwidth/channel (more channels)
 - Data compression (much easier in digital signal)
 - => better quality and more channels

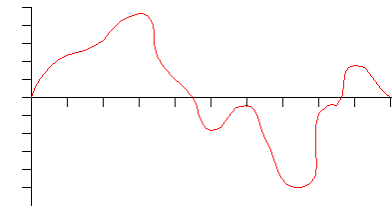
Audio Representation



Sound “shape” of
“Hello”

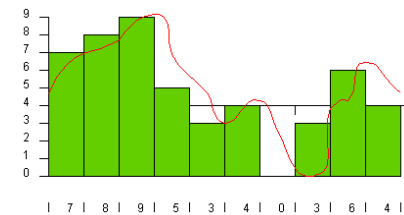
<http://electronics.howstuffworks.com/analog-digital.htm/printable>

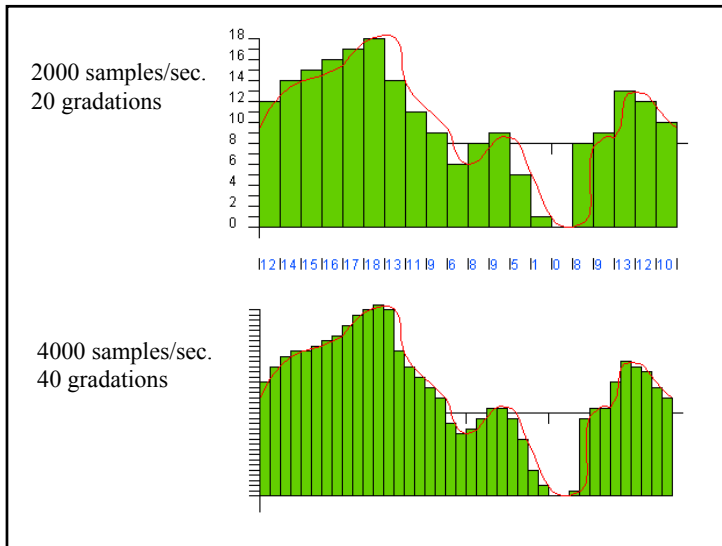
Original signal



Sampling (取樣)

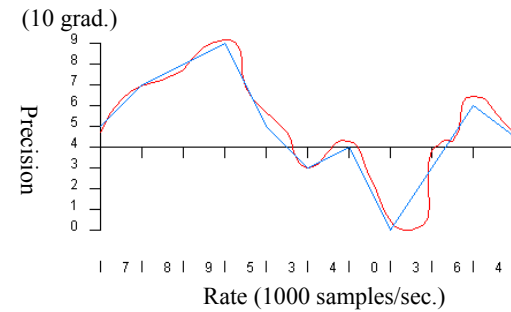
1000 samples/sec.
10 gradations





Sampling from analog signal to digital signal

- Sampling rate (samples/second)
- Sampling precision (gradations)



- Audio CD
Sampling 44.1 kHz, 16 bits (2 bytes) per sampling,
two channels (stereo)
 $2 \text{ bytes} * 2 * 44.1 \text{ k} = 176.4 \text{ k} (\sim 150 \text{ k}) \text{ bytes / second}$
Beethoven 9th symphony 74 min. and 42 sec.
 $176.4 \text{ k} * (60 * 74 + 42) \sim 750 \text{ M} (\text{or } 800 \text{ M}) \text{ bytes}$
- MP3 (MPEG-1 Audio layer-3): using data
compression to reduce the required storage space
to 1/12 to 1/10.

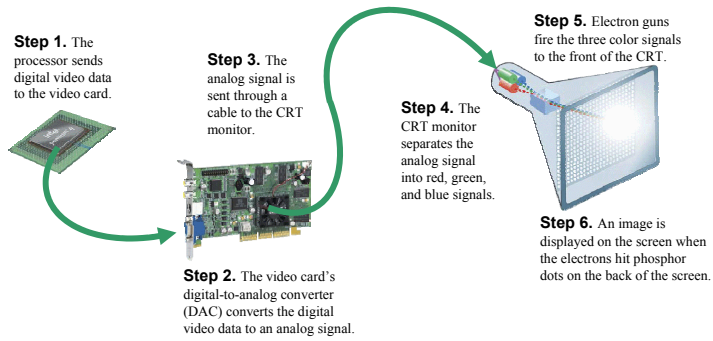
Image Representation



Display Devices

• How does video travel from the processor to a CRT monitor?

➤ **Video card (also called a graphics card) converts digital output from computer into analog video signal**



Display Resolution and Required Memory

Video Memory	Color Depth	Number of Colors	Maximum Resolution
1 MB	8-bit	256	1024 x 768
	16-bit	65,536	800 x 600
	24-bit	16.7 million	800 x 600
2 MB	8-bit	256	1024 x 768
	16-bit	65,536	1280 x 1024
	24-bit	16.7 million	1024 x 768
4 MB	24-bit	16.7 million	1024 x 768
6 MB	24-bit	16.7 million	1280 x 1024
8 MB	32-bit	16.7 million	1600 x 1200
16 MB	32-bit	16.7 million	1920 x 1440
32 MB	32-bit	16.7 million	2048 x 1536
64 MB	32-bit	16.7 million	2048 x 1536
128 MB	32-bit	16.7 million	2048 x 1536

Representing Images

- **Bit map:** an image is considered to be a collection of dots, each of which is called a pixel. Facsimile machines, video cameras, scanners. (GIF and JPEG compress such images into more manageable sizes.) can not be easily rescaled to any arbitrary size.
- **Vector:** an image is represented as a collection of lines and curves. Scalable fonts. Not able to provide the photographic quality images.

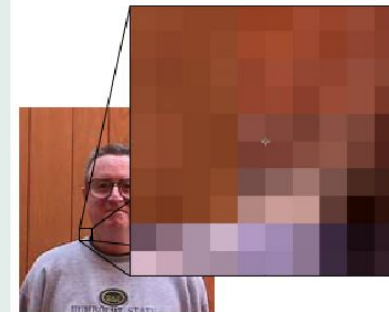
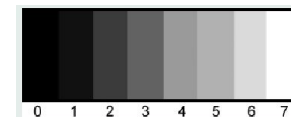
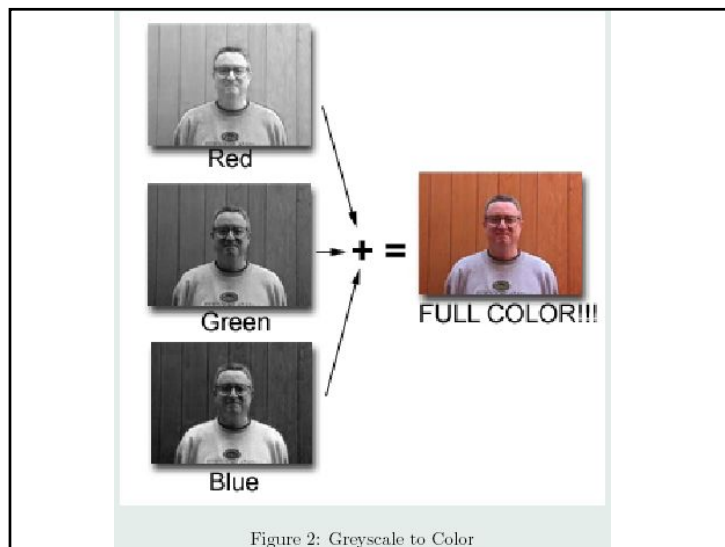


Figure 1: Images are created out of pixels



Grayscale of 3 bits



Data Compression

- Why the image file size is usually much smaller than the required memory size in the display for the same resolution?
 - Imagine how much memory required to store a image? E.g. 1024x768 full color ~3MB, but it is usually much smaller.
 - => Data compression

Data Compression

- **Run-length encoding** – replacing long sequences of the same value with a code indicating the value that is **repeated** and the number of times it occurs in the sequence. $253+118+87=458$
- e.g. 253 ones and 118 zeros and 87 ones = 458 bits
- Compression rate approx. $\sim (3 \text{ bytes} + 3 \text{ bits}) / 458 \text{ bits} = (27/458) \sim 6\%$ **Times + 0/1**
- E.g. black-white images, cartoon images

Data Compression

- **Relative encoding** – record the **differences** between consecutive data blocks rather than entire blocks.
- Picture differs slightly from the preceding one, e.g. consecutive frames of a motion picture
- Ex: If only 4% of the two consecutive frames differ, the compression rate $\sim 4\%$
 - 台北市羅斯福路四段一號 台大計算機中心 100室
 - 台北市羅斯福路四段一號 台大計算機中心 101室
 - 台北市羅斯福路四段一號 台大計算機中心 102室
 - 台北市羅斯福路四段一號 台大計算機中心 201室

Data Compression (*)

- Frequency-dependent encoding – the length of the bit pattern used to represent a data item is inversely related to the frequency of the item's use. Huffman codes
- e.g. use less space for (e, t, a), and more space for (z, q, x)
- Ex: an article with 1000 characters (including symbols)
~ 8 bits * 1000 = 8,000 bits
- (e, t, a) with 3 bits, and the rest with 9 bits
700 characters of (e, t, a) and 300 characters of the rest.
~ 3 bits * 700 + 9 bits * 300 = 4,800 bits
=> Compression rate ~ 4,800/8,000 = 60%

Lempel-Ziv encoding

- Adaptive dictionary encoding – the dictionary is allowed to change during the encoding process.
- LZ77 – start by actually quoting the initial part of the message, but at some point we would shift to representing future segments by triples, each consisting of two integers followed by a symbol from the message.

Figure 1.28: Decompressing

x y x x y z y

- a. Count backward 5 symbols.

x y x x y z y

- b. Identify the four-bit segment to be appended to the end of the string.

x y x x y z y x x y z

- c. Copy the four-bit segment onto the end of the message.

x y x x y z y x x y z x

- d. Add the symbol identified in the triple to the end of the message.

LZ77 encoding

- xyxxyzy(5,4,x)(0,0,w)(8,6,y)
- xyxxyzyxxyz(0,0,w)(8,6,y)
- xyxxyzyxxyzw(8,6,y)
- xyxxyzy|xxyz|w|zyxxyzy
- xyxxyzyxxyzwzyxxyzy

Compressing Images

- Three-byte-per-pixel
- GIF (Graphic Interchange Format) – reducing the number of colors that can be assigned to a pixel to only 256 (good for cartoon images)
- Each of the 256 potential pixel values is associated with a red-green-blue combination by means of a table known as the palette.
- Comparison: Chinese characters – reference table
-> another method of data compression

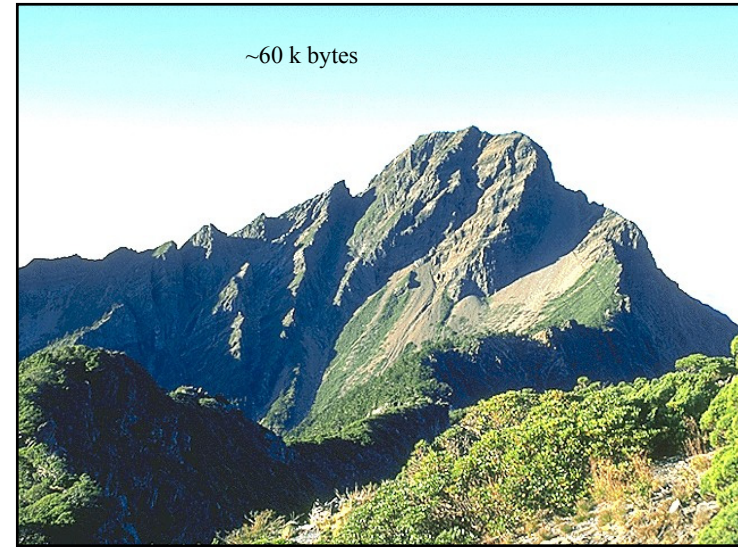
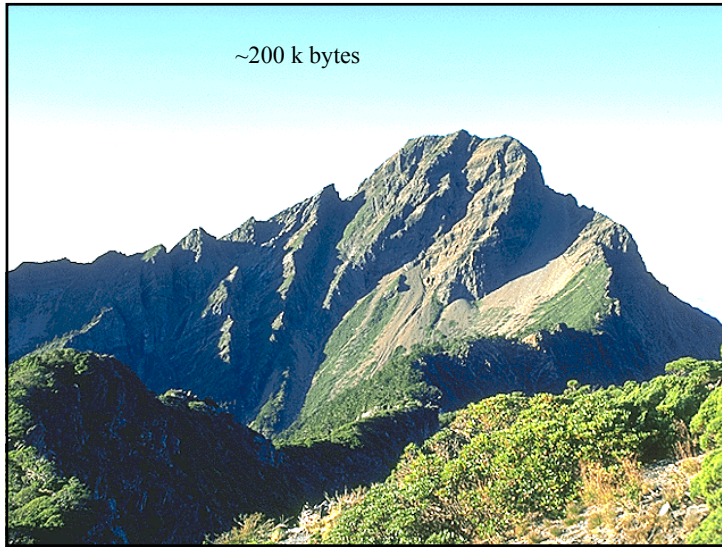
JPEG (Joint Photographic Experts Group)

- Encompasses several methods of image representation, each with its own goals.
- Lossless mode
- Implying that no information is lost in the process of encoding the picture.
 - Space is saved by storing the difference between consecutive pixels rather than the pixel intensities themselves. (relative encoding)
 - These differences are then coded using a variable-length code to further conserve storage space.

JPEG (lossy mode)

- Each pixel is represented by three components - a brightness component and two color components
- The human eye is more sensitive to changes in brightness than to changes in color.
- Encode each brightness component but averaging the values of the color components over the four pixel blocks and recording only these 4 block averages.
- 4-pixel block is presented by only 6 values (4 brightness values and 2 color values)
- The compression rate is in the range of 1/20.

- Additional space is saved by recording data that indicate how the various brightness and color components **change (difference)** rather than their actual values. The degree to which nearby pixel values differ can be recorded using fewer bits than would be required if the actual values were recorded. (discrete cosine transform)



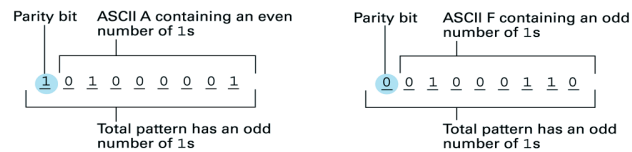
MPEG – Motion Picture Experts Group

- Start a picture sequence with an image similar to JPEG's baseline and then to represent the rest of the sequence using relative encoding techniques.
- The relative encoding is taken within one picture and two or more consecutive pictures. (Mostly, only small fraction of the image varies, while the rest keeps the same.)
 - e.g. internet movie (Due to different compression rates, you may see a blurred image in some fast or drastically changing motion due to limited bandwidth.)
 - See the cartoon

Communication Errors

- **Parity** bits
- Long bit patterns are often accompanied by a collection of parity bits making up a checksum.

Figure 1.29: The ASCII codes for the letters A and F adjusted for odd parity



- An error in any one of the check bits will cause exactly one parity check violation, while an error in any one of the message bits will cause violations of a distinct pair of parity checks.

- The parity can be either even or odd. If the received data are different from the assigned parity, there exist some communication errors.
->Redo the action to get correct data.

Note: Parity check does not ensure the correctness of communication, e.g. even number of erroneous bits. (but the possibility is usually much lower than that of single erroneous bit.)

Communication Errors

- Error-Correcting Codes:
 - Hamming distance between two patterns to be the number of bits in which the two differ.
 - X = 1000 1011 and
 - Y = 0100 1001
 - Z = 1000 0111
 - Hamming distance of (X,Y) = 3
 - Hamming distance of (Y,Z) = 5

An error-correcting code

Symbol	Code
A	000000
B	001111
C	010011
D	011100
E	100110
F	101001
G	110101
H	111010

Decoding the pattern 010100 using the code

Character	Distance between the received pattern and the character being considered
A	2
B	4
C	3
D	1 <i>Smallest distance</i>
E	3
F	5
G	2
H	4

The closest character is 'D'.

Single-error-correcting code

- M_1 M_2 M_3 C_1 C_2 C_3
 - 0 0 0 0 0 0
 - 0 0 1 1 1 0
 - 0 1 0 0 1 1
 - 0 1 1 1 0 1
 - 1 0 0 1 0 1 $C_1 = M_1 \oplus M_3$
 - 1 0 1 0 1 1 $C_2 = M_2 \oplus M_3$
 - 1 1 0 1 1 0 $C_3 = M_1 \oplus M_2$
 - 1 1 1 0 0 0
- \oplus : exclusive OR (XOR)

- ECC with Hamming distance of **three** allows us to detect **two errors** per pattern and correct **one error**, while EEC with Hamming distance of five, to detect four errors and correct two errors.