Bits, bytes and digital information

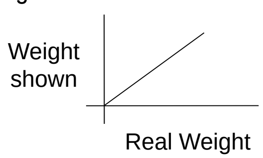
Lecture 2 – COMPSCI111/111G SS 2016

Today's lecture

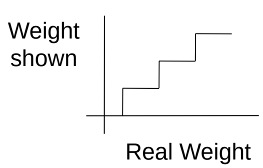
- Understand the difference between analogue and digital information
- Convert between decimal numbers and binary numbers

Analogue vs digital information

- Information in the real world is continuous
  - Continuous signal

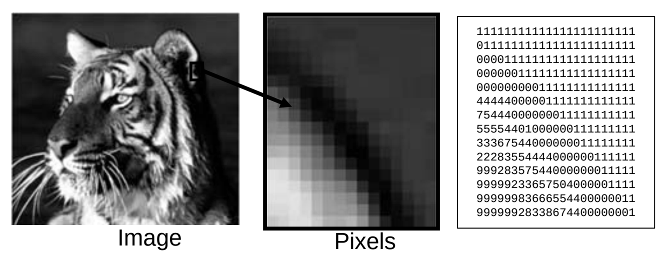


- Information stored by a computer is digital
  - Represented by discrete numbers



Encoding information

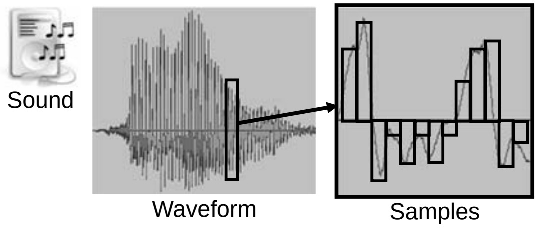
- Real world information is stored by a computer using numbers
- Visual information



1. Give each pixel colour a number.
2. Let the computer draw the numbers as coloured pixels (eg. black = 0).

Encoding information

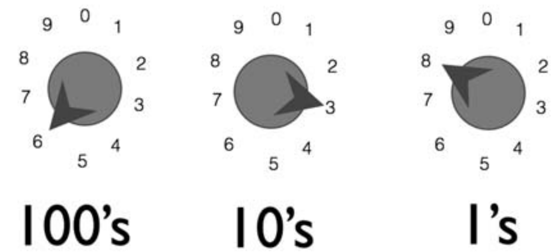
- Sound information



1. Give each sample a number (height of green box).
2. Let the computer move the loudspeaker membrane according to the samples.

Decimal numbers

- The decimal number system is a **base 10** system
- You can think about it as a dial with 10 positions:



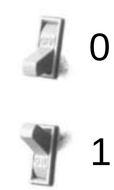
600 + 30 + 8 = 638

Decimal numbers

- The number of dials corresponds to the numbers that can be generated
- So:
  - Possible numbers = 10^n
  - Range = 0 to 10^n-1
- For example, if we have four dials…
  - Therefore:
    - 10^4 = 10,000 possible numbers
      - Note 10 = base 10 and 4 = number of dials
  - Range = 0 to 9999 (ie. 0 to 10^4-1)

Binary numbers

- A number whose value is either 0 or 1
- Too complex to create 10 states in electronic circuitry. Much easier if we have two states like a switch, ON and OFF
- This is how binary numbers work; 0 usually means OFF and 1 usually means ON



Binary numbers

- Each binary number is called a **bit (binary digit)**
- Using strings of bits, we can represent any whole number
- Using one switch (ie. one bit) we can generate up to two numbers (ie. 0 and 1)

Binary numbers

- Using two switches (ie. two bits) we can generate up to four numbers

Binary	Decimal
00	0
01	1
10	2
11	3

Binary numbers

- So:
  - Possible numbers = 2^n
  - Range = 0 to 2^n-1
- For example, if we have four switches…
  - Therefore:
    - 2^4 = 16 possible numbers
      - Note 2 = base 2 and 4 = number of switches
  - Range = 0 to 2^4-1:
    - 0000_2 to 1111_2
    - 0_{10} to 15_{10}

Converting binary to decimal

- With decimal numbers, each dial's position has a value:

$1 * 10^3 \quad + \quad 5 * 10^2 \quad + \quad 2 * 10^1 \quad + \quad 1 * 10^0$

1000 + 500 + 20 + 1

= 1521_{10}

- Similarly with binary numbers, each switch's position has a value. Convert 1101_2 to decimal:

$1 * 2^3 \quad + \quad 1 * 2^2 \quad + \quad 0 * 2^1 \quad + \quad 1 * 2^0$

1 * 8 + 1 * 4 + 0 * 2 + 1 * 1

= 13_{10}

Converting binary to decimal

- Convert 10011_2 to decimal
- Convert 35_{10} to binary

Prefixes

- A group of 8 bits is a **byte**
  - A group of 4 bits is a **nibble**
- Bytes are the common unit of measurement for memory capacity
- There are two sets of prefixes:
  - Decimal
  - Binary

Decimal prefixes

10^n	Prefix	Symbol	Decimal
1	none		1
10^3	kilo	K	1000
10^6	mega	M	1,000,000
10^9	giga	G	1,000,000,000
10^{12}	tera	T	1,000,000,000,000
10^{15}	peta	P	1,000,000,000,000,000
10^{18}	exa	E	1,000,000,000,000,000,000
10^{21}	zetta	Z	1,000,000,000,000,000,000,000
10^{24}	yotta	Y	1,000,000,000,000,000,000,000,000

Binary prefixes

2^n	Prefix	Symbol	Decimal
2^0	none		1
2^{10}	kibi	Ki	1024
2^{20}	mebi	Mi	1,048,576
2^{30}	gibi	Gi	1,073,741,824
2^{40}	tebi	Ti	1,099,511,627,776
2^{50}	pebi	Pi	1,125,899,906,842,624
2^{60}	exbi	Ei	1,152,921,504,606,846,976
2^{70}	zebi	Zi	1,180,591,620,717,411,303,424
2^{80}	yobi	Yi	1,208,925,819,614,629,174,706,176

Prefixes in Computer Science

- Both decimal and binary prefixes are used in Computer Science
- Decimal prefixes are preferred because they are easier to calculate, however binary prefixes are more accurate

Binary prefix	Decimal prefix	Value (bytes)
8 bits	1 byte	same
1 KiB	1 KB	1024 ≠ 1000
1 MiB	1 MB	1,048,576 ≠ 1,000,000

Example - hard disk sizes

- A 160GB hard disk is equivalent to 149.01GiB
  - 160GB = $160 * 10^9$
  - 149.01GiB = $(160 * 10^9) / 2^{30}$

Examples

- Which has more bytes, 1KB or 1KiB?
- How many bytes are in 128MB?
- What is the decimal prefix for 10^{12} bytes?

Summary

- Computers use the binary number system
  - We can convert numbers between decimal and binary
- Decimal prefixes and binary prefixes are used for counting large numbers of bytes