CM12002
Computer Systems Architectures

Data Representation

Fabio Nemetz

There are only 10 types of people in the world:
those who understand binary, and those who don't.

Data Representation

Summary

In this lecture:

- Numeration systems
- Converting between different numeration systems.

Data Representation

Computers are required to represent a variety of forms of data:

- Positive (or *unsigned)* integers*.*
- Signed Integers.
- Alphanumeric characters and strings.
- Real numbers.
- Program instructions.
- Addresses of memory locations and external devices.

Two-state representation

Electronic computers (*except the* ENIAC*) are based on *two-state* devices (transistors and logic gates).

Electronically, we need to distinguish only between, for example:

- voltage and no voltage, or
- current and no current, or
- switch on and switch off, or
- electrical pulse and no electrical pulse.

This can be related to a particular numeration system:

the binary system.

**Research homework*

Numeration systems

Before we study the binary system, it is important to understand numeration systems in general.

All numeration systems are *representational,* i.e. a form of coding. Coding should be devised so that the system:

- has few symbols that are easy to remember;
- is unambiguous;
- is economical in use (or presentation);
- is a useful quantitative measure;
- can be easily manipulated, e.g. to perform arithmetic.
- The Roman system was a classic counter-example:
- XXIV + XCVI = ?
- 24 + 96 = 120

Symbol	Value
I	1
V	5
X	10
L	50
C	100
D	500
M	1,000

For fun: http://www.onlineconversion.com/roman_numerals_advanced.htm

Numeration systems

The decimal numeral system:

- Symbols: 0 1 2 3 4 5 6 7 8 9
- Base: 10 (there are 10 symbols)
- Decimal: from Latin decem (meaning 10)
- But why do we use it?

- Coincides with the number of fingers

Numeration systems

In the decimal system, how do we represent numbers larger than 9?

We use combinations of these digits:

$352 = 300 + 50 + 2 =$

$3x100 + 5x10 + 2x1=$

$3x10^2 + 5x10^1 + 2x10^0$

We call it a positional notation.

Powers of 10
$10^0 = 1$
$10^1 = 10$
$10^2 = 100$
$10^3 = 1000$ (thousand)
$10^4 = 10000$
$10^5 = 100000$
$10^6 = 1000000$ (million)
$10^7 = 10000000$
$10^8 = 100000000$
$10^9 = 1000000000$ (billion)

Numeration systems

Decimal notation: not the only way to represent numbers

- If we use 8 symbols (0, 1, 2, 3, 4, 5, 6, 7)
  - our new base is 8 (octal numeral system)
- If we use 2 symbols (0 and 1)
  - our new base is 2 (binary numeral system)

Numeration systems

134_8 means 134 in **base 8 (or in octal)**

Convert 134_8 to decimal.

$1 \times 8^2 + 3 \times 8^1 + 4 \times 8^0 = 64 + 24 + 4 = 92$

1101_2 means 1101 in **base 2 (or in binary)**

Convert 1101_2 to decimal.

$1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 = 8 + 4 + 0 + 1 = 13$

Numeration systems

$1FCB_{16}$ means 1FCB in **base 16 (or in hexadecimal)**

Convert $1FCB_{16}$ to decimal.

$1 \times 16^3 + 15 \times 16^2 + 12 \times 16^1 + 11 \times 16^0 =$

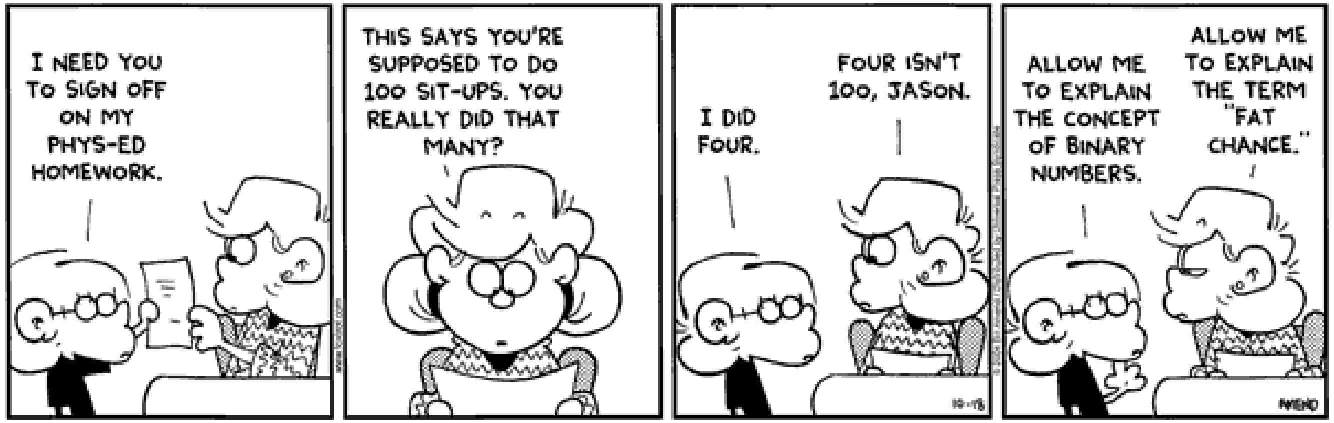
$4096 + 3840 + 192 + 11 = 8139$

Hexadecimal	Decimal
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
A	10
B	11
C	12
D	13
E	14
F	15

Binary System

Let’s count in binary

Binary	Decimal
0	0
1	1
10	2
11	3
100	4
101	5
110	6
111	7
1000	8



Decimal, Binary, Octal, Hexadecimal

Decimal number	Binary representation	Octal representation	Hexadecimal representation
0	0	0	0
1	1	1	1
2	10	2	2
3	11	3	3
4	100	4	4
5	101	5	5
6	110	6	6
7	111	7	7
8	1000	10	8
9	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F
16	10000	20	10

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There are only 10_2 types of people in the world:

those who understand binary, and those who don't.

There are only 10 types of people in the world:
those who understand binary, those who don't and
those who didn’t expect this joke to be in base 3 ☺

Why do Computer Scientists always confuse Halloween and Christmas?

Because Oct 31 = Dec 25

$31_8 = 25_{10}$

To be continued …