Technical Foundations
Lecture 1: Introduction

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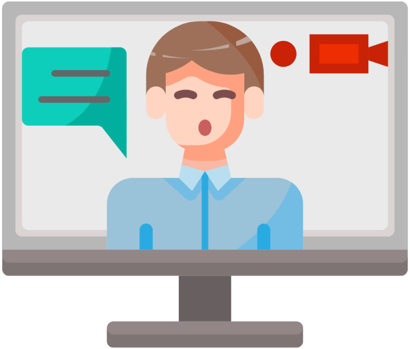
Why

- We can all speak Arabic
- We can also speak English
- You can build and understand the structure of the sentences in Arabic and in English
- What about computers?



How

- Computers can only understand 0s and 1s
- Everything you see in a computer as to be translated
- Circuits have to be built to make sure we can produce all the needed functionalities

What

- Study how the translation happens
- Simulate Circuits
- Study how using only 0s and 1s we can represents everything and build all required functions.

General Information

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- TAs: Eng. Yahya ElGhobashy yahya.elghobashy@giu-uni.de, Zeyad Shaheen: zeyad.shaheen@giu-uni.de
- Floyd, T.L.: Digital Fundamentals. Pearson, 2014.
  Wirth, N.: Digital Circiut Design. Springer, 1995.
- Share your questions through piazza:
  `piazza.com/giu-uni.de/winter2022/cs103`

Credits and a Huge Thank You to Prof. Dr. Slim Abdennadher, Assoc. Prof. Amr Elmougy

Tentative Grading

- Quizzes: 20%
- Projects: 20%
- Midterm Exam 20%
- Final Exam: 40%

Numbers we use

- Think about the number 734.
- We pronounce it seven **Hundred** and **Thirty Four**
- This number is build as follows: $734 = 700 + 30 + 4$
- $734 = 7 * 100 + 3 * 10 + 4 * 1$
- In terms of 10
- $734 = 7 * 10^2 + 3 * 10^1 + 4 * 10^0$

Positional numbering systems: decimal

1, 10, 100, ... are all powers of ten!

The meaning of a decimal number:

$$5 \times 10^6 + 6 \times 10^5 + 2 \times 10^4 + 3 \times 10^3 + 1 \times 10^2 + 3 \times 10^1 + 9 \times 10^0 = 5,623,139$$

- This is why it is called decimal
- The position determines the power of 10, with which the digit at the position has to be multiplied!
- The first position is with $10^0 = 1$, the second with $10^1 = 10$, and so on...

Different bases

Question

How do I choose a good base?

- Which one is best? 10? 20? 60?

- Base 10 allows to counting with your fingers
- Base 20 allows to counting with your fingers and toes

Bases Contd.

Use sli.do Code: 154935

- Base 10 allows me to have 10 digits: 0, 1, 2, ... 9
- Base 5 allows me to have 5 digits: 0, 1, 2, 3, 4
- Base n allows me to have n digits from ? to ?

Bases Contd.

Which base would work for computers ?

Computer numbering system

Question

What base should we chose for a Computer?

Computers run with electricity

There are two distinct states of most electrical devices (including the transistor which is the basis of computers):

off

on

⇒ So we should chose a base two system!

Two important conversions: Binary to decimal

Problem:

Convert a binary number into decimal

1. Write down the binary number
2. Write down the positional weight (the factor)
3. Multiply each digit by its weight
4. Do the sum

Example

Number:	1	0	1	1	0	0	0	1
Positional weight:	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Factor:	128	64	32	16	8	4	2	1

$$128 + 0 + 32 + 16 + 0 + 0 + 0 + 1 = 177_{10}$$

Conversion to Decimal

- Multiply every digit by its weight
- The weight is the $base^{location}$

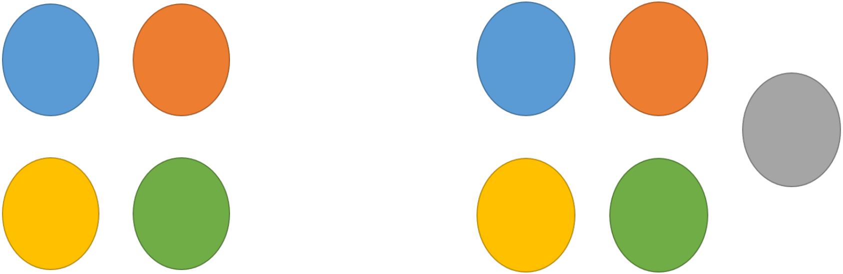
$$\text{Convert } 121_3 \text{ to decimal}$$
$$121_3 = 1 * 3^2 + 2 * 3^1 + 1 * 3^0 = 16$$

Check Point

Convert 125_6 to decimal

Use sli.do Code: 154935

Remainder: Divide into groups of 2



Decimal to binary

Problem:

Convert a decimal number into binary

Solution by successive division:

1. Divide by the base (*i. e.*, 2) and write down the remainder
2. Repeat division until the quotient equals 0
3. Read the binary number by reading the remainders (bottom-up)

Convert 43 into binary

Division	Quotient	Remainder
43/2	21	1
21/2	10	1
10/2	5	0
5/2	2	1
2/2	1	0
1/2	0	1

$43_{10} = 101011_2$

Conversion in general

Both algorithms work for any base!

Example (Convert (base 60) to decimal:)

Number:		
Positional weight:	60^1	60^0
Factor:	60	1

$1500 + 46 = 1546_{10}$

Example (Convert 1546 (base 10) to hexadecimal)

Division	Quotient	Remainder
$1546/16$	96	10
$96/16$	6	0
$6/16$	0	6

$1546_{10} = 60A_{16}$

Check Point

Convert 125_{10} to binary

Use sli.do Code: 154935

Introduction to binary numbers

For the binary system we use the powers of 2:

$$2^0 = 1, 2^1 = 2, 2^2 = 4, 2^3 = 8, 2^4 = 16, \ldots$$

Example

$$5,623,139_{10} = 10101011100110101100011_2$$

Observations

- We need two different symbols (on–off, true–false, 1–0, high–low, *etc.*)
- To write the decimal number 5,623,139 in binary, we need 23 digits.
- A modern computer usually uses 64 digits, which allows for roughly 18.4 thousand trillion numbers.

Terms and names

Some terms:

- **Bit**: The single binary digit (0 or 1), the smallest unit of information.
- **Byte**: Eight bit, which means up to 256 different numbers in positional binary.
- **Word**: The base number of digits used by a computer, usually eight byte or 64 bit.

Familiar bases

Observation

It is tedious to switch between binary and decimal!

It is much easier with these bases:

- Octal, or base 8
- Hexadecimal, or base 16 (do not mix up with “hexagesimal”!)

Octal, hexadecimal, and binary

Imagine a numbering system with base 8 (Octal)

- Numbers: 0, 1, 2, 3, 4, 5, 6, 7

Example translation:

$$101\underbrace{101}_{5}001\underbrace{001}_{1}011\underbrace{011}_{3}110\underbrace{110}_{6}{}_2 = 5136_8$$

Imagine a numbering system with base 16 (Hexadecimal)

- Numbers: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

Example translation:

$$1010\underbrace{1010}_{A}0101\underbrace{0101}_{5}1110\underbrace{1110}_{E}{}_2 = A5E_{16}$$

Summary

- We are used to a base 10 positional system
- Other bases (20, 60) were used through history
- Generally, a base n system encodes numbers as follows:

$$(x_i x_{i-1} \ldots x_1 x_0)_n = x_i \times n^i + x_{i-1} \times n^{i-1} + \ldots + x_1 \times n^1 + x_0 \times n^0$$

- We can convert any positional system into any other positional system
  1. Write down the digits
  2. Multiply each digit by its positional value (the respective power of the base)
  3. Add the products
- Some conversions are very convenient (binary–octal, binary–hexadecimal, ...)
- Binary is ideal for computers

Conversion in general

Hence you can now convert any base to any other base

Problem

Convert N_1 with base n to N_2 with base m

Solution:

1. Convert N_1 of base n to a decimal number N
2. Convert N to the number N_2 base m

Note:

The conversions also work directly as a transition from base n to base m (without the indirection over decimal).
It is just unusual.

Thank you :)