The Beauty and Joy of Computing

Lecture #3 : Creativity & Abstraction

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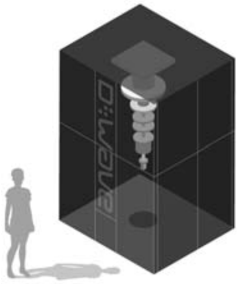
QUANTUM COMPUTING: WORK IN PROGRESS



Current commercial applications of the quantum computer D-Wave (used by NASA and Google) have nebulous speed up benefits compared with modern computers. Faster and slower on different problems. Still being refined.

`http://www.wired.com/2014/06/d-wave-quantum-speedup/`

Computing is a Creative Activity

- "Creativity and computing are prominent forces in innovation; the innovations enabled by computing have had and will continue to have far-reaching impact.
- At the same time, computing facilitates exploration and the creation of knowledge.
- This course will emphasize these creative aspects of computing.

Computing enables people…

- …to translate intention into computational artifacts.
- A computational artifact is created by human conception using software tools.
- Examples of computational artifacts include
  - digital music, videos, images
  - documents
  - combinations of these. E.g.,
    - infographics
    - presentations
    - web pages.

Computing enables people…

- …to create digitally!
- Creating…
  - knowledge
  - tools
  - expressions of ideas
  - solutions to problems.
- Creating digitally…
  - requires understanding and using software tools.
  - can be done by…
    - combining and modifying existing artifacts
    - creating new artifacts.

Collaboration is an essential part…

- …of creating computational artifacts.
- Collaboration facilitates multiple perspectives in developing computational artifacts.
- A computational artifact can reflect collaborative intent.

We can analyze computational artifacts…

- …for correctness, functionality, and suitability.
- A computational artifact may have weaknesses, mistakes, or errors depending on the type of artifact.
  - For example, music created by a program may not have an error but may simply be hard to listen to.
- The functionality and suitability (or appropriateness) of a computational artifact may be related to how it is used or perceived.

Computing extends traditional forms…

- …of human expression and experience.
- Computer music can be created by synthesizing sounds, by sampling existing music, or by recording and manipulating sounds.
- Creating digital effects, images, and animations has impacted and transformed the movie industry.
- Computing enables creative exploration of real and synthetic phenomena.

Programs can be developed…

- …for creative expression or to satisfy personal curiosity.
- A program developed for creative expression or to satisfy personal curiosity may have visual, audible, or tactile results; or the program may affect a computer or system without such results.
- Programs developed for creative expression or to satisfy personal curiosity may be developed with different standards or methods than programs developed for widespread distribution.
- A program or the results of running a program may be shared with others.

Programs can be developed…

- ...to solve problems, create new knowledge, or help people, organizations, or society.
  - however, the goals may be realized independently of the original purpose of the program.
- Computer programs and the results of running the programs have widespread impact on individuals, organizations, and society.

Numbers: Positional Notation

- **Number Base B □ B symbols per digit:**
  - **Base 10 (Decimal): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9**
  - **Base 2 (Binary): 0, 1 (In binary digits are called “bits”)**
  - **Base 16 (Hexadecimal): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F**
- **Number representation:**
  - **$d_{31}d_{30} \ldots d_1d_0$ is a 32 digit number**
  - **value = $d_{31} \times B^{31} + d_{30} \times B^{30} + \ldots + d_1 \times B^1 + d_0 \times B^0$**
- **Binary 0b11010** $= 1\times2^4 + 1\times2^3 + 0\times2^2 + 1\times2^1 + 0\times2^0$
  $= 16 + 8 + 2$
  $= 26$
- **Hex 0x1A** $= 1\times16^1 + 10\times16^0$
  $= 16 + 10$
  $= 26$
- **One hex digit (four bits) is a “nibble”. Two (eight bits) is a “byte” (values 0-255)**
- **N bits □ at most 2^N things**

Abstraction (revisited): Numbers

- Number bases, including binary and decimal, are used for reasoning about digital data.
- Bits represent binary data using base two digits: zero and one.
- Hexadecimal, or base-16, is often used in reasoning about data such as colors in images.
- Different bases help in reasoning about digital data; digital data is stored in bits.

Abstraction (revisited): Digital Data

- A combination of abstractions is used to represent digital data.
- At the lowest level all digital data are represented by bits.
  - Said another way, bits can represent anything!
- Bits are grouped to represent higher-level abstractions including numbers and characters.
  - Logical values? 0 → False, 1 → True
  - Colors? 00 → Red, 01 → Green, 10 → Blue
  - Characters? 00000 → ‘a’, 00001 → ‘b’, …
- Higher-level abstractions such as Internet protocol (IP) packets, images, and audio files are comprised of groups of bits that represent different parts of the abstractions.

Binary Sequences to Represent Data

- A finite representation is used to model the infinite mathematical concept of a number.
- In many programming languages the fixed number of bits used to represent integers limits the range of integer values, and mathematical operations can result in overflow or other errors.
- In many programming languages the fixed number of bits used to represent real numbers (represented as "floating-point numbers") limits their range, and mathematical operations can result in round-off and other errors.

A.M. TURING AWARD

WILLIAM ("VELVEL") MORTON KAHAN

United States – 1989

For his fundamental contributions to numerical analysis. One of the foremost experts on floating-point computations. Kahan has dedicated himself to "making the world safe for numerical computations"!

Interpretation of a Binary Sequence…

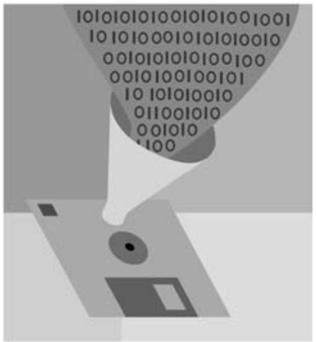
- …depends on how it is used (e.g., as instruction, number, text, sound, or image).
- The sequence of bits that represents…
  - …an instruction may also represent data processed by that instruction.
  - …a character/letter may also represent a number.
  - …a color in an image may also represent a sound in an audio file.

being digital

NICHOLAS NEGROPONTE

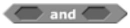
SW and HW built on multiple abstractions!

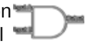
- Software is built using low- and high-level abstractions…
  - such as expressions, statements, data types, functions, and libraries.
  - that represent hardware, such as device drivers and game controllers.
- Hardware is built using low- and high-level abstractions such as chips, memory, and storage.



Binary Data is processed by…

- …physical layers of computing hardware, including gates, chips, and components.
- A logic gate is a hardware abstraction that models a Boolean function.

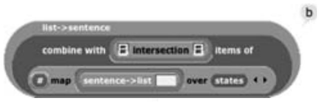




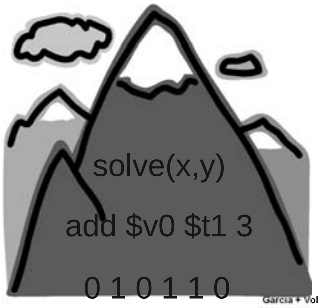
- A chip is an abstraction composed of low-level components and circuits that performs a specific function such as memory, CPU, encryption, and more.
- A hardware component can be low level like a transistor or high level like a video card.

Programming languages, from low to high level…

- …are used in developing software.
- Low-level programming languages, such as assembly, are closer to the machine level and provide fewer abstractions for the programmer.
- High-level programming languages provide more abstractions for the programmer and are easier for humans to use for reading and writing code.
- Code in a high-level programming language is typically automatically translated into code in a lower-level language to be executed on a computer; this is done by a compiler or an interpreter.



```
list->sentence
combine with ( intersection ) items of
  # map ( sentence->list ) over states
```



Abstractions everywhere!

- Applications and systems are designed, developed, and analyzed using levels of hardware, software, and conceptual abstractions.
  - E.g., Mobile applications and systems
  - E.g,. Web services (both an application and a system)

Summary

- Creativity
  - You will create interesting and relevant artifacts with the tools and techniques of computer science.
- Abstraction
  - This course will include examples of abstractions used in modeling the world, managing complexity, and communicating with people as well as with machines.
  - You will learn to work with multiple levels of abstraction while engaging with computational problems and systems.