中国科学院大学
University of Chinese Academy of Sciences

CS101

Overview

Course Introduction

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The set of lecture slides include 30 files, each for a 45-minute lecture.
This set is only a suggestion. A lecturer or student may skip some slides.

Outline

- Administration
- Objective: what are learned in CS101
- Method: how to learn CS101

- Reminder
  - Set up your computer for programming by next week
    - Use programs this week
    - Start to do programming next week

These slides acknowledge sources for additional data not cited in the textbook

1.1 Administration Information

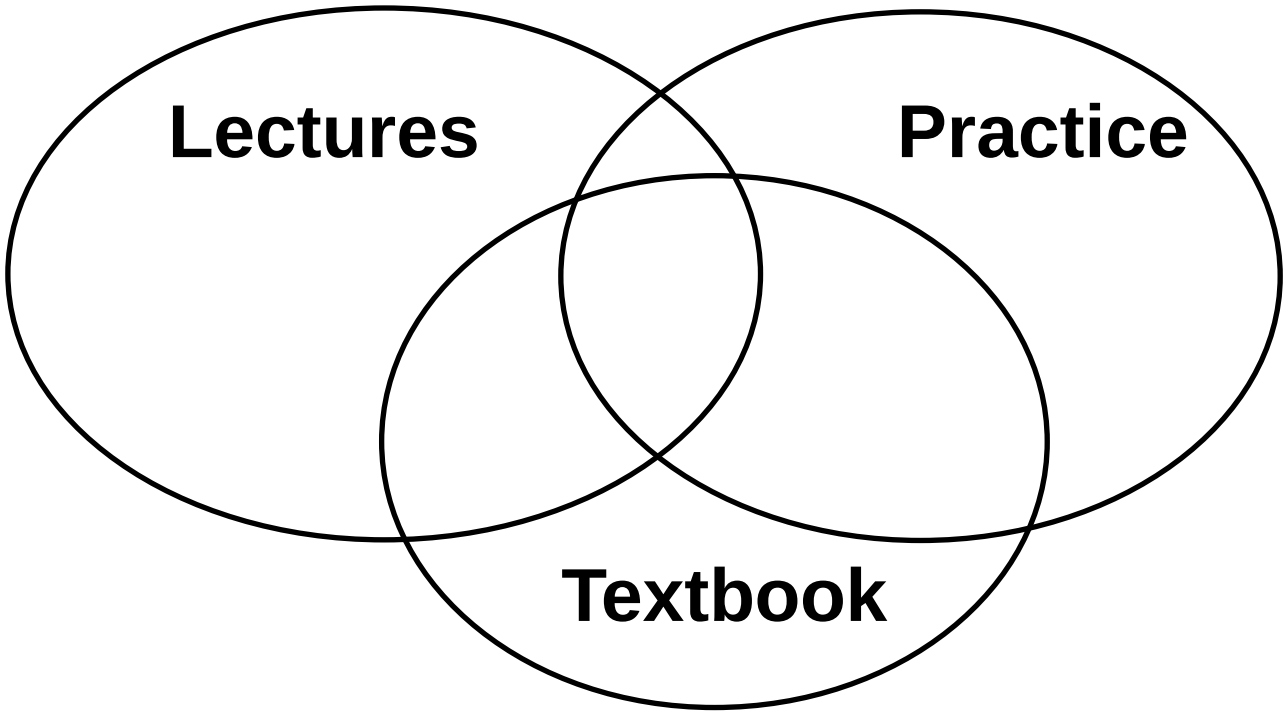
- Textbook
  - Zhiwei Xu, Jialin Zhang, *Computational Thinking: A Perspective of Computer Science*, Springer, 2021
- Professors
  - Zhiwei Xu, zxu@ict.ac.cn
  - Jialin Zhang, zhangjialin@ict.ac.cn
- TAs
  - Lab TAs:
  - Q&A TAs:
- Grading policy
  - Total = Participation × 60% + Final × 40%
    - Participation = Lectures + Labs + HWs + Projects

Syllabus

Week	Chapter	Lecture-1	Lecture-2	Project Lab	Deadline: 23:30 Sunday
1	Overview	Course Introduction	Computational Thinking	None	
2	Symbol Manipulation	The CS and IT Field	Data As Symbols	None	Homework-1
3		Programs As Symbols	Von Neumann Model	None	Homework-2
4	Logic Thinking	Propositional Logic-1	Propositional Logic-2		
5		Turing Machines	Turing Machines	Turing Adder	
6		Predicative Logic	Power and Limit		Homework-3
7	Algorithmic Thinking	Bubble Sort and Quick Sort	Algorithms, Asymptotic Notations		Turing Adders Submission
8		Divide and Conquer	Stable Matching	Human Sorter	
9		Reduction	P vs NP		Homework-4
10		Human Sorter Field Run			
11		Human Sorter Class Presentation		None	Human Sorter Report
12	Systems Thinking	Systems Overview	Data & Control Abstractions	Text Hider	
13		Modularization-1: Combinational Circuits & Sequential Circuits	Modularization-2: Instruction Pipeline and Software Stack		
14		Seamless Transition-1: Cycle Principle and Robustness Principle	Seamless Transition-2: Exhaustiveness Principle and Amdahl's Law		Homework-5
15	Network Thinking	Network Overview	Web Programming	Personal Artifact	Text Hider Report
16		Connectivity: Naming & Topology	Protocol Stack		
17		Network Effect	Responsible Computing		Homework-6
18	Whole Book	Term Review		None	Personal Artifact Report
19	Whole Book	Final Exam		None	

Syllabus

- The syllabus is executed by combining three activities
  - Studying textbook
  - Attending lectures and other classes
  - Practice, including homeworks and projects



1.3 Grade distributions of past classes

- Every year
  - Most students scored above 80/100
  - Some earned full score 100/100
  - Some still failed

Class Year	2014	2015	2016	2017	2018	2019
Class Size	357	288	345	363	361	332
Score: 90~100	3%	31.6%	15.1%	18.5%	19.4%	16.6%
Score: 80~89	40%	48.3%	40.3%	44.6%	39.3%	42.5%
Score: 70~79	48%	15.6%	29.9%	23.4%	22.7%	20.5%
Score: 60~69	8%	3.8%	11.9%	7.2%	10.8%	10.0%
Score: <60	1%	0.7%	2.9%	6.3%	7.8%	10.5%

Class of 2019 took the course, online only, in Feb-July 2020

2. What are learned in CS101

- Learn the elementary and the way of thinking
  - **Overview** of the CS discipline and the IT field
    - CS is the study of computational processes
      - for **problem solving and creative expression**
      - that are **correct, smart, and practical**
  - **Ability** to **create** computers and computer applications
    - Not just **use** computer applications
  - **Principles** of computational thinking
    - Logic thinking, algorithmic thinking, systems thinking
    - Network thinking
- Focus on the elementary knowledge
  - See “Problem-Solving Examples” of Textbook

2.1 Examples

- Examples of Problem-Solving and Creative Expression

(a) Sort a class of students: from order by name to order by height

(b) How big is the panda?

(c) Part of the *Kitty Band*

Design a working computer

- Design a human computer
  - With complete hardware and software
  - To realize a quicksort algorithm
  - In realizing a computer application

A team computer sorts a team of students: from order by name to order by height
Photos are blurred for privacy Photos credits: Haoming Qiu

Hide text in a picture

- Write a program
  - to hide the text of Shakespeare's *Hamlet*
    - in a picture file Autumn.bmp
    - such that the doctored file shows no visible difference from the original picture
- and another program to recover the text

HAMLET

DRAMATIS PERSONAE

CLAUDIUS king of Denmark. (KING CLAUDIUS:)

HAMLET son to the late, and nephew to the present king.

…..

ACT ISCENE I Elsinore. A platform before the castle.
…..
PRINCE FORTINBRAS Let four captains
Bear Hamlet, like a soldier, to the stage;
For he was likely, had he been put on,
To have proved most royally: and, for his passage,
The soldiers' music and the rites of war
Speak loudly for him.
Take up the bodies: such a sight as this
Becomes the field, but here shows much amiss.
Go, bid the soldiers shoot.
[A dead march. Exeunt, bearing off the dead
bodies; after which a peal of ordnance is shot off]

Original picture

After careless hiding

After careful hiding

Create a Personal Artifact

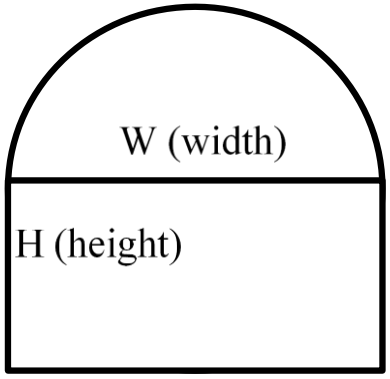
- Create a dynamic webpage of creative expression
  - Also enhance the capability of self-learning
  - Demo by accessing webpage on local-host
  - Demo by accessing webpage on class website

Graphics credit: Siyue Li

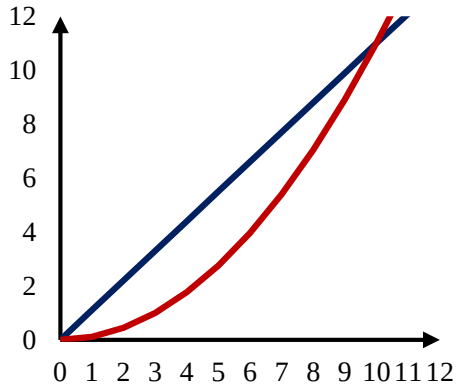
Siyue Li created the Kitty Band artifact in 3 days (FTE)
50% thinking, making
50% coding

Know a new scientific paradigm

- Step-by-step computational processes are powerful
  - Can solve problems unsolvable before
    - **Demo** to show the computational process of computing the size of the panda area, by accessing the dynamic webpage panda.html
- A class of computational processes, called computer **simulation**, offers the third paradigm of scientific inquiry



(a) School Mathematics
Regular shapes



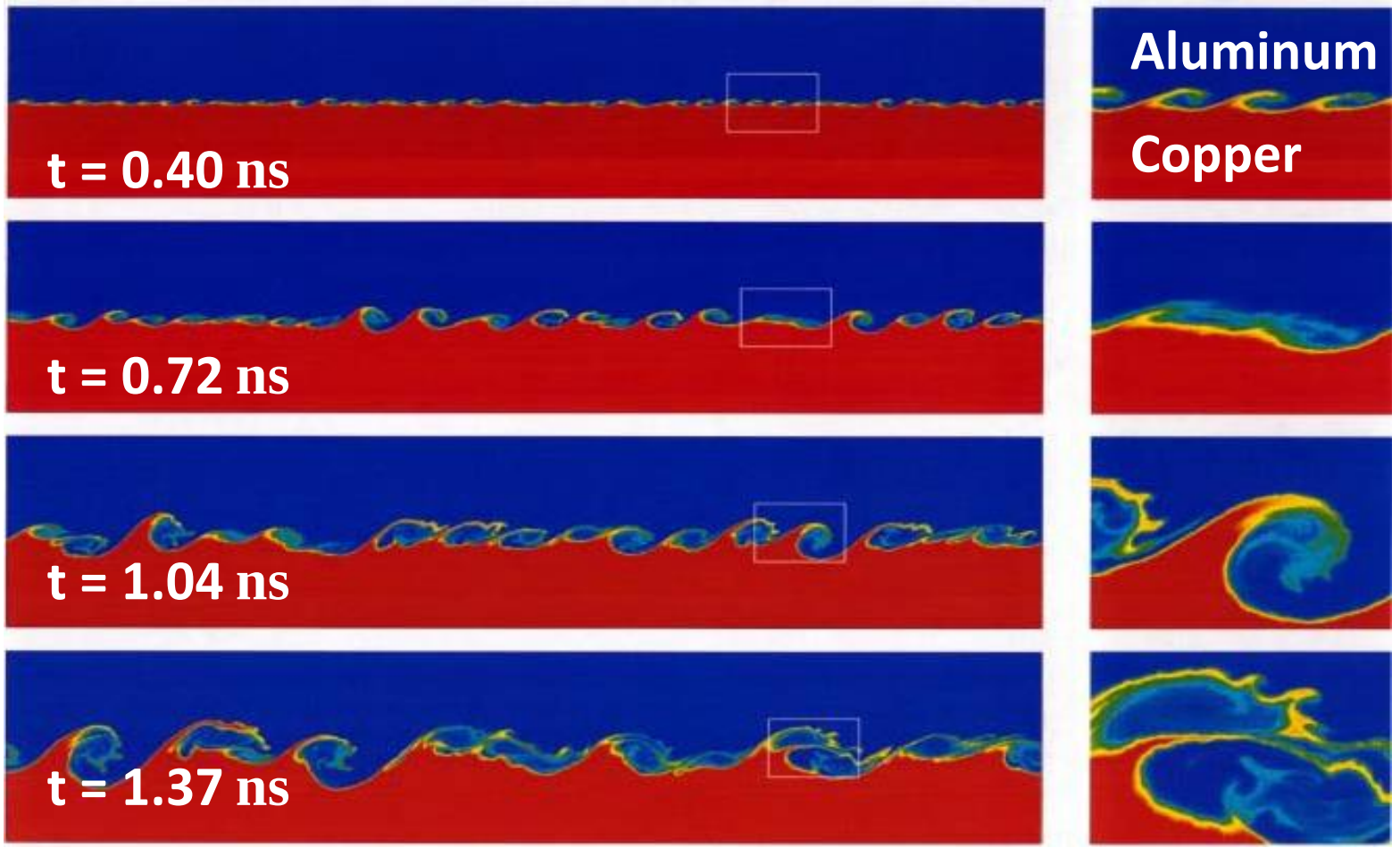
(b) College Mathematics
Curly shapes

(c) Computer Science
Irregular shapes

Graphics credit: Hongrui Guo

See the invisible: Atoms in the Surf

Simulation using 9 billion atoms reveals the Kelvin-Helmholtz Instability (**video**)
Temperature: 2000K; relative speed: 2000 m/s; 36 million CPU hours



Richards D F, Krauss L D, Cabot W H, et al. (2008). Atoms in the Surf: Molecular Dynamics Simulation of the Kelvin-Helmholtz Instability Using 9 Billion Atoms. https://arxiv.org/abs/0810.3037 and www.youtube.com/watch?v=Wr7WbKODM2Q.

2.2 Elementary knowledge covered

- Introduce most elementary knowledge listed in the US Academies Report
  - US National Research Council. Computer Science: Reflections on the Field, Reflections from the Field. Washington D.C: National Academies Press, 2004.

US Academies Concepts	**Concepts Learned in This Course**
Abstract computer	Turing machine, automata
Real computer	Laptop computer, WWW
Computer applications	Outcomes of the four projects, programming exercises
Symbol manipulation	Digital symbols from integer, character, image, to programs
Abstractions	Multiple abstractions, from circuit level to application level
Algorithms	Divide and conquer, dynamic programming
Artificial constructs	Students Computer for Quicksort
Exponential growth	P vs. NP, wonder of exponentiation
Fundamental limits	Turing computability, Godel's incompleteness theorems
Action associated with human intelligence	Reasoning with Boolean logic

2.3 Elementary knowledge learned by creation

- Most knowledge units learned by creation

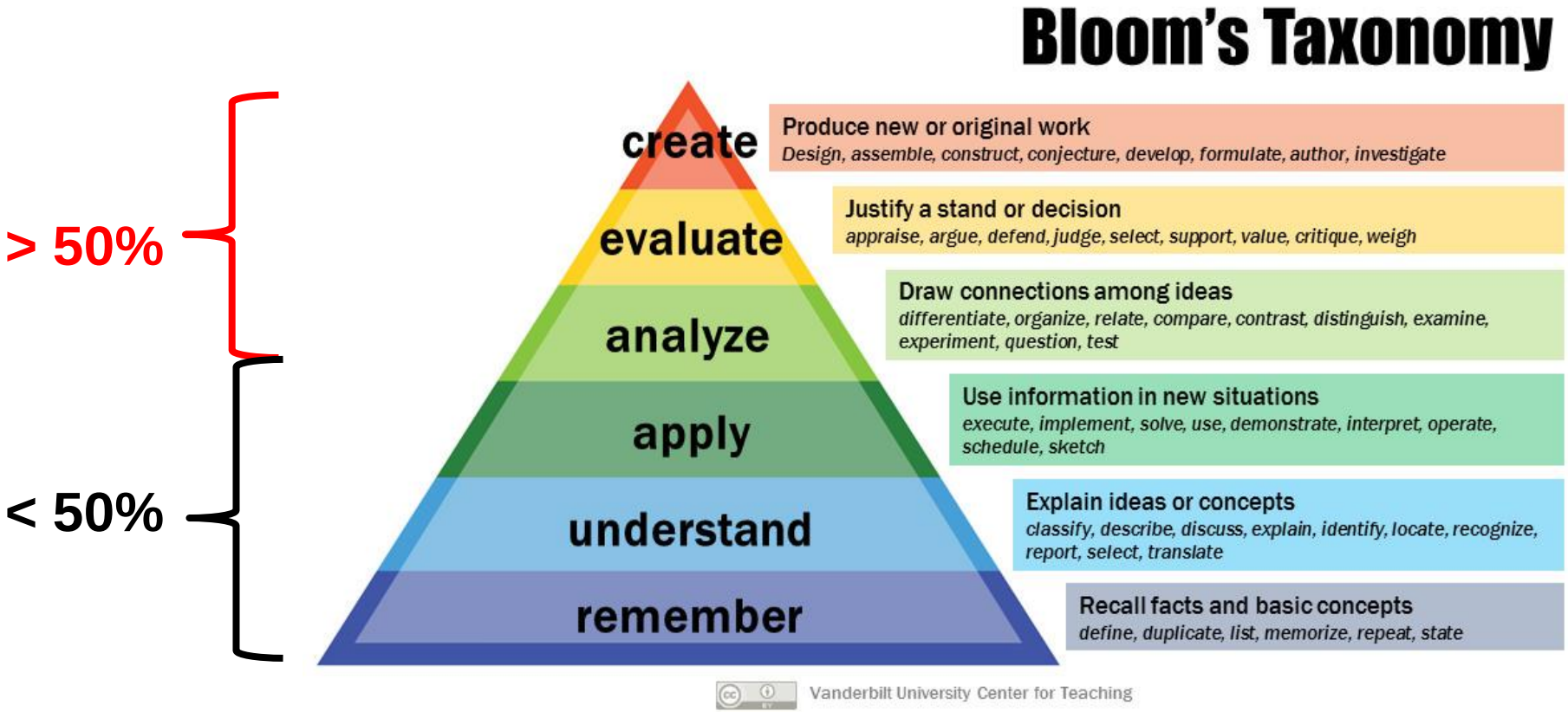
Data Type	bit (1 bit), hexadecimal number (4 bits), byte (8 bits), uint8 (8-bit unsigned integer), integer (64 bits); array (n elements of the same type), slice (a descriptor pointing to an array); text file, BMP image file; hypertext and hyperlink	
Software	Algorithm	Smart method of information transformation, such as quicksort, hiding text in a BMP file, etc.
	Program	Code realizing algorithms in computer language, such as hide.go in the Text Hider project
	Process	Program in execution, such as the “hide” process running in a Linux environment
	Instruction	The smallest unit of software, directly executable by computer hardware
von Neumann Architecture: a computer model bridging software and hardware		
Hardware	Instruction Pipeline	The basic hardware mechanism to automatically execute any instruction
	Sequential Circuit	More precisely, only consider Synchronous Sequential Circuit comprised of combinational circuits and state circuits and driven by a clock signal; equivalent to the automata concept
	Combinational Circuit	Aka Boolean circuit, realizing a Boolean function

3. How to learn CS101

- Method
  - Mind-active and hands-on learning (动脑动手主动式学习)
    - Actively attend lectures and labs
    - Independently complete six assignments and four projects
    - Heed Knuth's Test and Bloom's Taxonomy
- They all form one method
  - Unity of Knowledge and Action (UKA)
  - In Chinese: 知行合一
- For most students, the method should be
  - Intellectually stimulating
  - Fun

3.1 Learn the elementary, but aim at upper layers

- Aim at upper layers of Bloom's taxonomy
  - E.g., after learning adder, design a subtractor
    - Not merely duplicate, or apply with different parameters



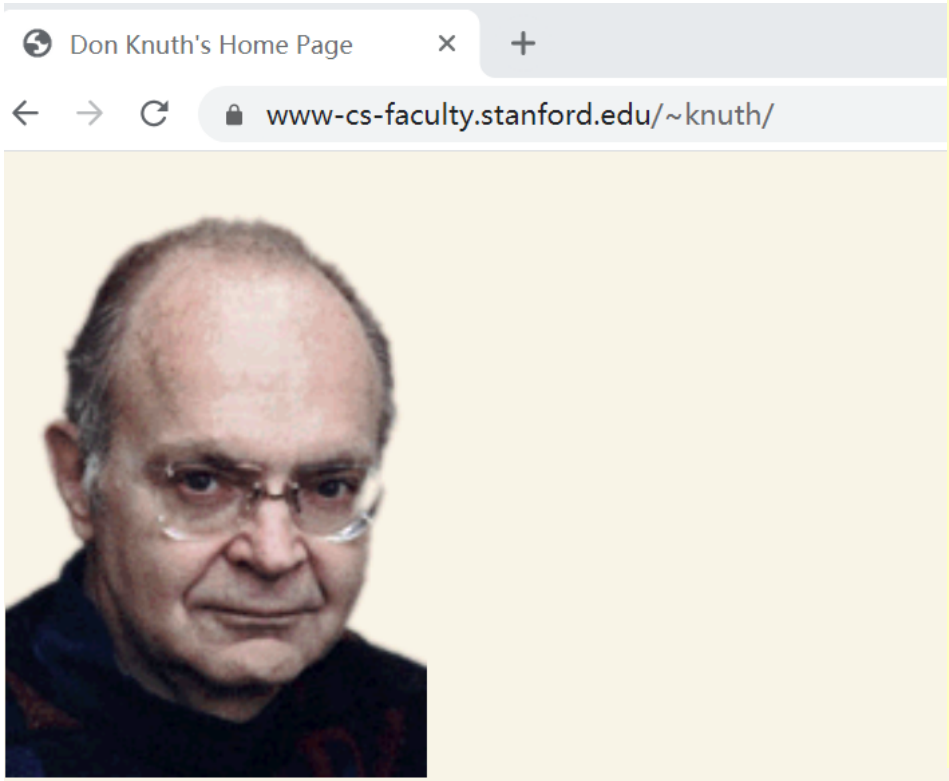
https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

3.2 Enable students to pass Knuth's Test

"The **ultimate test** of whether I **understand something** is if I can **explain it to a computer**. I can say something to you and you'll nod your head, but I'm not sure that I explained it well. But the computer doesn't nod its head. It repeats back exactly what I tell it. **In most of life, you can bluff, but not with computers**."

Donald Knuth, Feb 2020

Susan D'Agostino. The Computer Scientist Who Can't Stop Telling Stories. Quanta Magazine. April 16, 2020. https://www.quantamagazine.org/computer-scientist-donald-knuth-cant-stop-telling-stories-20200416.



Three ways to pass Knuth's Test

- Design and run a correct program on a computer
  - Programming exercises (altogether < 300 LoC)
  - The Human Sorter project
- Solve a homework problem
  - Now the computer is the student himself
    - Prove that the halting problem is not computable
    - Decide whether "responsible disclosure" or "full disclosure" is the right action
- Perform a thought experiment
  - How does a computer work?
    - How is a simple loop of computational process executed?
      - From the high-level language code level, the instruction level, down to the gate level.
  - Prove statements without domain knowledge
    - Given "congruent triangles are similar", show that
      If two triangles are not similar, then they are not congruent.

3.3 UKA (Unity of Knowledge and Action)

- 知行合一
- A pedagogic methodology borrowed from Wang Yangming (王阳明, 1472–1529), a Chinese educator from the Ming Dynasty
- An essence of this methodology is to learn knowledge with mind-active, hands-on actions
  - Cannot achieve it by memorization

https://en.wikipedia.org/wiki/Wang_Yangming

- Textbook example of a UKA unit

1. Conversions between binary and decimal number representations