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

计算机科学导论

概述1-1

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什么是计算机科学

- **计算机科学**是研究计算过程的科学。
  - 计算过程是信息变换过程，即通过操作数字符号变换信息的过程，涉及信息在时间、空间、语义层面的变化。
- **计算思维** = 计算机科学的专业思维方式
  - 通过研究计算过程有效解决问题，从而认识世界、理解世界、改造世界。

本年度课程特点

- 引进双语教学
  - 教科书、课件和教学平台都有中英文版
    - 英文版教科书
    - 他们不完全一样，总的来讲
      - 中文版内容更多（例如，教科书三分之一是创新故事）
      - 英文版讲解更细（例如，二进制与十进制转换）
  - 相互参照更加有利于同学们提升学习效率

- 实践更适合本课程的教学方法
  - 知行合一在本课程的具现 = 高德纳测试
  - 个性化教学
  - 迭代式学习（从错误中学习）

1-minute quiz（课堂小测验）

- 姓名：　　学号：
- 你是否拥有一台笔记本电脑：　（是/否）
  - 如果拥有，是什么平台：
    - 例如，x86 Windows，x86苹果，M1苹果，龙芯电脑
- 你是否有程序设计经验：　　（是/否）
  - 如果回答“是”，请用一句话描述你已有的编程能力
  - _____。
  - **例如**
    - 做过Excel项目，涉及宏编程
    - 学过单片机编程
    - 在高中学过VB课程，通过学业水平考试
    - 学过C，获全国青少年信息学奥赛省二等奖
    - 熟悉C++，获全国青少年信息学奥赛金牌

提纲

1. 课程管理信息
2. 学什么：课程教学目标
3. 如何学：知行合一创造性学习
   - 不光是用（Apply），还要设计（造，Create）

4. **课后任务（有问题与助教交流）**
   - 两周内读完中文教科书第一章
   - 安装Linux+Go编程环境并运行hello.go程序

1. 课程管理信息

1.1 课程管理基本信息

1.2 注意事项：不将就“短板思维”

1.3 往届同学们的经验教训

1.4 关于推荐信

1.1 课程管理基本信息

- **任课教师**：徐志伟、张家琳
  - zxu@ict.ac.cn
  - zhangjialin@ict.ac.cn
- **助课教师**：
  - 实验课助教：田国敬、郭城、郭泓锐、孙元
  - 答疑助教：裴晓坤、杨泽超、林志达、李思悦、陈国凯
  - 其他助教：俞子舒
- **成绩**：平日成绩×60% + 期末考试成绩×40%
  - **平日成绩**：实验，作业，课堂参与等
- **效率提示**（MIT经验）
  - 上课、记笔记；读教科书；做习题、完成实验

远程教学期间

- 请大家关注课程网站和微信群通知，有任何问题及时联系老师或助教

QQ群：主要用于答疑
请扫码入群

微信群：主要用于发放课程通知，不用于答疑！

教学日历

可能会根据疫情情况变化进行调整，请大家留意微信群和课程网站的通知

周次	理论课（周五上午）		实验课（周三下午）		截止时间（周日23:30）
1	3月12日	绪论	3月10日	无	
2	3月19日	绪论	3月17日	无	作业1
3	3月26日	绪论	3月24日	无	作业2
4	4月2日	逻辑思维	3月31日	无	
5	4月9日	逻辑思维	4月7日	图灵机实验	
6	4月16日	逻辑思维	4月14日	图灵机实验	作业3
7	4月23日	算法思维	4月21日	图灵机实验	图灵机实验报告
8	4月30日	算法思维	4月28日	班级排序实验	
9	5月7日	算法思维	5月5日（5月8日补）	班级排序实验	作业4
10	5月14日	班级排序现场操作	5月12日	班级排序实验	
11	5月21日	班级排序报告	5月19日	无	班级排序实验报告
12	5月28日	系统思维	5月26日	信息隐藏实验	
13	6月4日	系统思维	6月2日	信息隐藏实验	
14	6月11日	系统思维	6月9日	信息隐藏实验	作业5
15	6月18日	网络思维	6月16日	个人作品	信息隐藏实验报告
16	6月25日	网络思维	6月23日	个人作品	
17	7月2日	网络思维	6月30日	个人作品	作业6
18	7月9日	期末总结	7月7日	无	个人作品报告
19	考试周				

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	Turing Adder	
5		Turing Machines	Turing Machines		
6		Predicative Logic	Power and Limit		Homework-3
7	Algorithmic Thinking	Bubble Sort and Quick Sort	Algorithms, Asymptotic Notations	Human Sorter	Turing Adders Submission
8		Divide and Conquer	Stable Matching		
9		Reduction	P vs NP		Homework-4
10		Human Sorter Field Run		None	
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 Text Hider Report
15	Network Thinking	Network Overview	Web Programming	Personal Artifact	
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	

徐志伟简介

- 1982年获成都电讯工程学院学士学位， 1984年获美国普度大学硕士学位，1987年获美国南加州大学博士学位
- 研究领域：高性能计算机体系结构、网络计算科学
- 担任曙光超级服务器、国家高性能计算环境、网格操作系统等多个国家和欧盟科研项目的技术负责人
- 历任曙光信息产业有限公司总工程师，中科院计算所研究员、副所长、总工程师、学位评定委员会主席、学术委员会主任，中国科学院大学教授
- 2005年以来，担任
  - 教育部大学计算机教指委委员
  - Journal of Computer Science and Technology主编，《计算机研究与发展》主编 IEEE Transactions on Computers、 IEEE Transactions on Services Computing、Journal of Parallel and Distributed Computing等国际期刊编委
- 教材与科普著作：
  - 《Scalable Parallel Computing》(McGraw-Hill)
  - 《操作系统：原理、技术与编程》(机械工业出版社)
  - 《网格计算技术》(电子工业出版社)
  - 《电脑启示录》(清华大学出版社)
  - 《计算机科学导论》(清华大学出版社)
  - 《Computational Thinking》(Springer-Nature)

张家琳简介

- 教育经历：
  - 2006/09 – 2010/06，清华大学 高等研究院，博士
    - 导师：姚期智教授
  - 2002/09 – 2006/06，清华大学物理系基础科学班，本科
- 工作经历：
  - 2012/08 – 至今，中国科学院计算技术研究所副研究员
  - 2010/08 – 2012/08，南加州大学计算机科学系博士后
    - 合作导师：滕尚华教授
- 研究方向
  - 理论计算机科学、算法设计与分析、复杂性理论、近似算法、在线算法、组合优化、计算博弈论、量子算法等

1.3 注意事项：不将就“短板思维”

- 尤其要注意：避免打击优秀同学的积极性

徐老师您好！

我是17XX班的XXX，我有一个关于信息隐藏实验成绩评定的问题，希望徐老师能帮助我。我昨天在查看书上信息隐藏实验成绩评定方案是看到“与预期图片是否相符”这一项，这应该就是指图片二进制的匹配吧？但是我在完成信息隐藏实验的时候没有完全按照书上所给的方式隐藏，而当时老师在给我们讲这个实验的时候以及网站上都没有说这个实验必须按照书的格式做。我在写程序的时候，因为考虑到如果将文本的长度隐藏在图片开头，整数隐藏与byte隐藏的步骤不能很好地用同一个函数统一起来，所以我没有采用这个方法，而是在隐藏完图片过后额外隐藏了一个标志结尾的符号。这意味着我的隐藏有信息的图片和“预期的图片”并不相符，难道说这样做会被评为零分吗？**我记得徐老师在上课的时候常说，要自己去思考问题，不要一味地接受权威的知识，我也是本着这一点，不想写出来的程序就仅仅是书上伪代码的翻译，希望在程序中体现自己的思考才用不同的方式处理文本长度的问题。**我当时把关注都放在如何更好地实现信息隐藏而么有太在意分数是怎么评价的，直到昨天看到成绩评定方案我才意识到我的这个实验可能没有分了。我很焦急，希望还能有一个补救机会。

更让我感到愧疚的是我还影响到了另一个同学（XXX）。这位同学原本不是很了解计算机，没有编程基础，但是学得很认真。她在完成这个实验的那几周里经常问我问题，我也用了两个下午的时间给她讲解她上课没有听懂的地方，讲解怎么编程，带她读书上程序和完成书后面的编程练习。最后又给她讲解信息隐藏实验的思路和一些细节的实现，也包括了用特殊标志代表结尾的方法。也许是因为我帮助她的缘故，她可能也没有太关注成绩的评定。

徐老师，这个实验的成绩评定方法能不能通融一下我的隐藏方法呢？因为这个方法也可以成功地隐藏和显示文本，能不能也算作成功的完成了实验呢？我之前联系过助教，他说以前都没有遇到这种情况。我知道没有注意查看成绩的评定方法是我个人的责任，我也应该为此负责，但是我真的非常希望老师能够给我之前提到的那位同学一次机会，因为这确实全是我的责任。

2018年教育部“龙芯杯”冠军

俞子舒四年级一学期伯克利成绩单

CALCENTRAL

Academic Summary

Student Profile

Name	Zishu Yu
Student ID	3034430598
Academic Career	UCB Ext
Level	Not Set
Cumulative GPA	4.000

Enrollment

Fall 2018

Class	Title	Un.	Gr.	Pts.
COMPSCI 188	Introduction to Artificial Intelligence	4.0	A+	16.0
EECS C106A	Introduction to Robotics	4.0	A	16.0
EL ENG 221A	Linear System Theory	4.0	P	0.0

Berkeley UNIVERSITY OF CALIFORNIA

1.4 往届同学的经验教训

- What can we see from grade distributions of past classes?
- Every year
  - Most students scored above 80/100; some earned full score 100/100
  - Some still failed, but could have done better

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

同学们需要尽快完成“高中思维→大学思维”转变

- 高中思维
  - 理想状况：德智体全面发展
  - 一些同学的现实情况：针对“第一职业”，即考上好学校好专业
  - 实践不好时的缺点：被动接受权威知识，效率低
    - 权威：教科书、老师、考题
- 大学思维
  - 不只是第一职业，是一生所需的知识、能力、思维方式
  - 即有学术传承，又学习前沿知识
  - 批判思维（critical thinking）能力与创造性学习能力
    - 从较多材料中主动领悟，更加深入地理解知识点
      - 举一反三；不是中学教科书样式
    - 从而初步理解“计算机科学技术”（即计算思维 ）

1.5 关于推荐信

- 很乐意为总成绩前10%的同学写推荐信
  - 我写的推荐信有“干货”，而不是套话
  - 最好集中在一段时间（不是在五个月给五个学校写信）

	Exceptional	Above Average	Average	Below Average	Unable to Judge
Intellectual Ability	✓				
Judgment and Maturity		✓			
Perseverance		✓			
Communication: Oral		✓			
Communication: Written		✓			
Analytical Ability	✓				
Imagination & Probable Creativity	✓				
Ability to work with others	✓				
Potential as a teacher		✓			
Self-Confidence	✓				
Overall Evaluation	✓				

本课程的设计
没有歧视
非计算机专业同学

Institute of Computing Technology, Chinese Academy of Sciences
No.6 Kexueyuan South Road, Beijing 100190, China

Phone: +86 10 62601166 Fax: +86 10 62567724 Homepage: www.ict.ac.cn

November 29, 2018

To Whom It May Concern,

I am pleased to write this recommendation letter for XXX, who is applying to your graduate program. I came to know XXX in March of 2016 when she enrolled in a freshman course I taught, Introduction to Computer Science, at University of Chinese Academy of Sciences. Although not majored in computer science, she did well and earned a final grade of 93/100, at the top 11% of the entire class of 288 students, and at the top 10% of 226 non-CS students.

Since then, XXX became more and more interested in computer science. That is why she has made the decision to switch to computer science for her graduate study and to obtain a master degree in CS. She has an inner drive towards this goal and serious about it. I am convinced that she will be an excellent addition to your graduate program.

If additional information is needed regarding this matter, please do not hesitate to contact me.

Sincerely yours,

Dr. Zhiwei Xu
Professor and CTO
Institute of Computing Technology, Chinese Academy of Sciences
University of Chinese Academy of Sciences
Email: zxu@ict.ac.cn
http://novel.ict.ac.cn/zxu/

2. 教学目标

2.1 **理解**计算思维，具备计算思维的基本**能力**

2.2 **掌握**知行合一知识点，即计算思维的**基本原理**

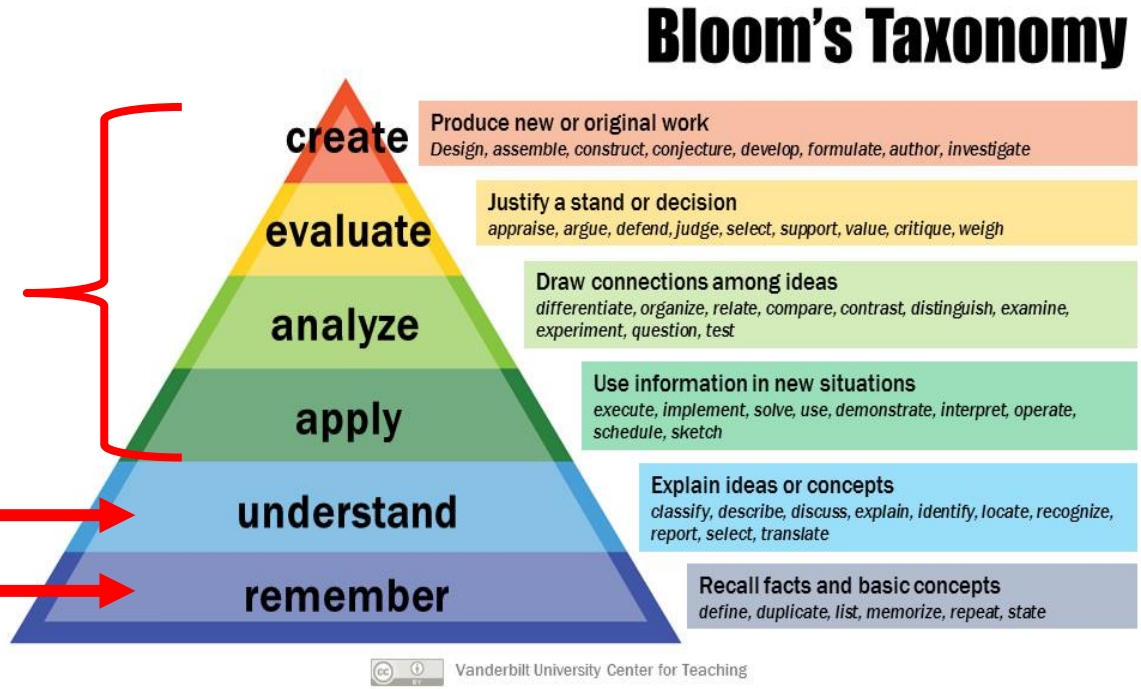
2.3 **了解**计算机科学领域的**入门知识**

知行合一
可创建、做出来
通过高德纳测试

60%

可向同学讲解
20%

自己可重现
20%



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

课程内容与教学方式

- 课堂讲授的五大单元（各三周）
  - 概貌（绪论）
  - 计算模型与逻辑思维
  - 算法思维
  - 网络思维
  - 系统思维
- 四个实验
  - 图灵机实验
  - 班级排序实验
  - 信息隐藏编程实验
  - 个人作品
- “书本知识”
  - 原理性知识
  - 实例类知识
  - 创新故事
  - 习题
  - 考试
- 动手动脑实验
  - 其中编程实验
    - 300行GO代码
    - Web编程

1周FTE=70小时

课内课外需要的总课时：1+1（128, 2周FTE）；1+2（3周）；1+3（4周）

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

- Each student will 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

- Each student will create a personal artifact of creative expression
  - In the form of a dynamic webpage
    - Also enhance the capability of self-learning
  - Demo by accessing webpage on local-host

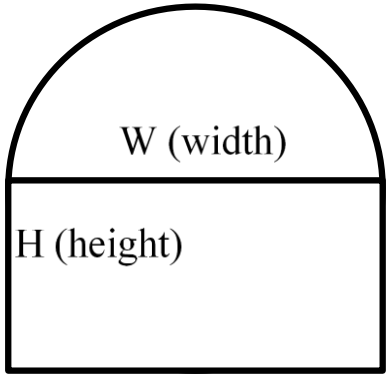
Graphics credit: Siyue Li

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

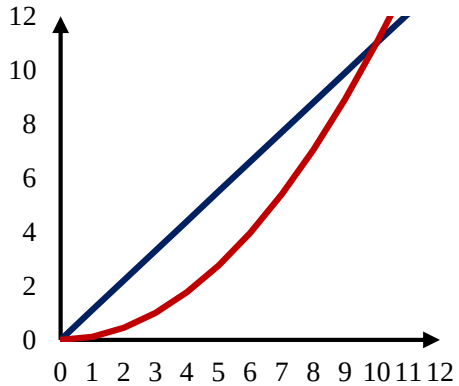
Know a new scientific paradigm

- 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
    - https://teacher.solid.things.ac.cn:7243/public/web/panda_area.html

- A class of computational processes, called computer **simulation**, offers the third paradigm of scientific inquiry



(a) School Mathematics
Regular shapes



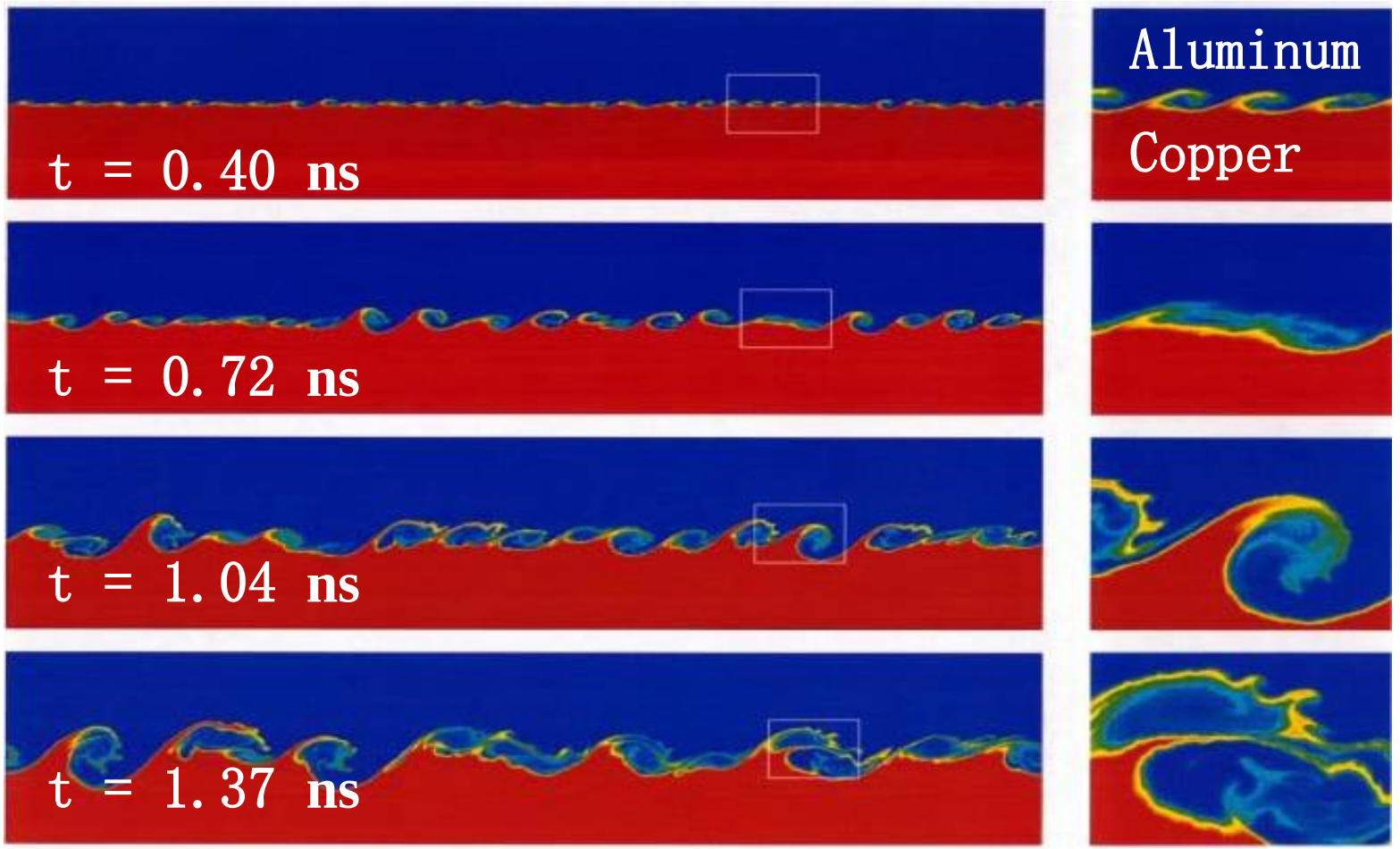
(b) College Mathematics
Curly shapes

(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

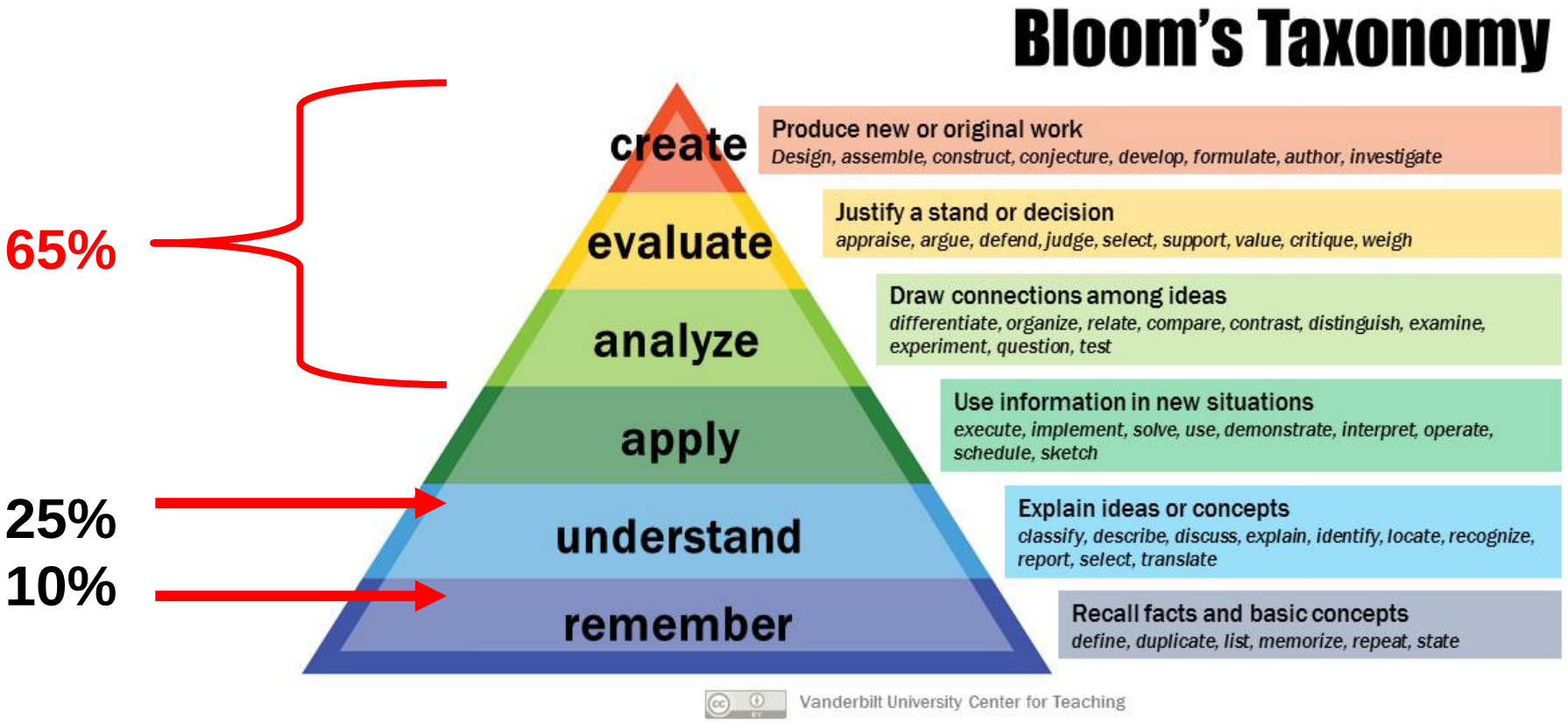
Data Type	bit (1 bit), hexadecimal number (4 bits), byte (8 bits), uint8 (8-bit unsigned integer), integer (64 bits); array (n elements of the same type), slice (a descriptor pointing to an array); text file, BMP image file; hypertext and hyperlink	
Software	Algorithm	Smart method of information transformation, 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



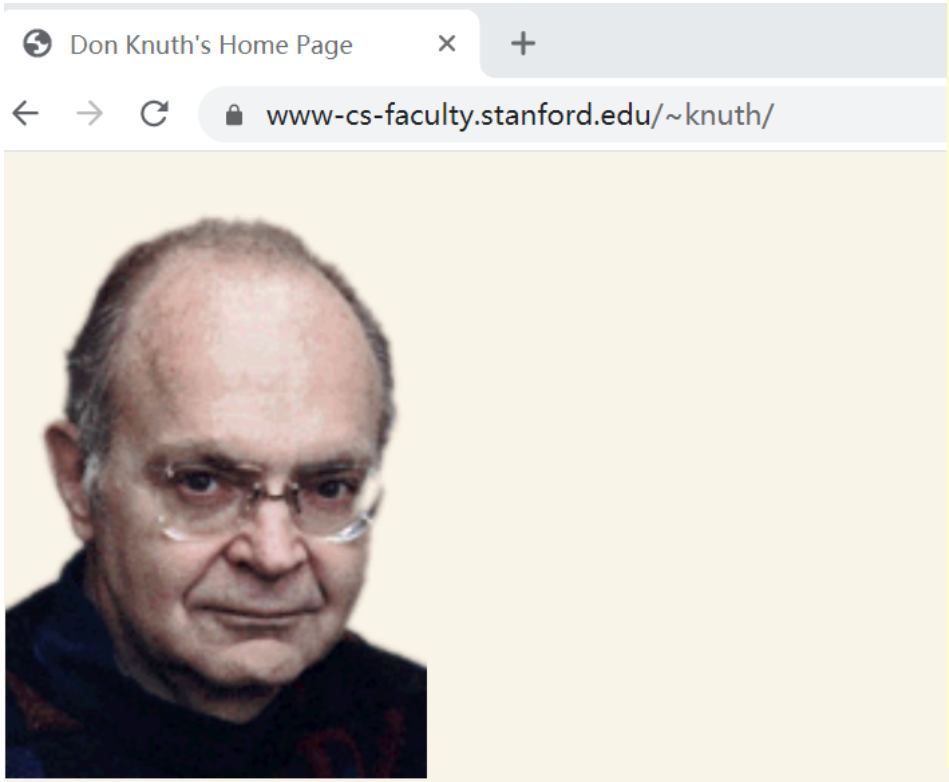
https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

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)

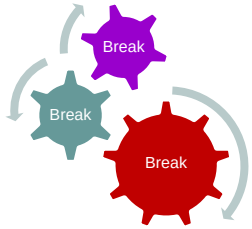
- 知行合一
- A pedagogic methodology borrowed from Wang Yangming (王阳明, 1472–1529), a Chinese educator from the Ming Dynasty
- An essence of this methodology is to learn knowledge with mind-active, hands-on actions
  - Cannot achieve it by memorization

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

- Textbook example of a UKA unit

1. Conversions between binary and decimal number representations

Take-Home Messages



- Learn the elementary and the way of thinking
  - The two (CS & CT) are essentially the same thing
    - **Overview** of the CS discipline and the IT field
    - **Ability** to create computers and computer applications
    - **Principles** of computational thinking
  - Focus on the elementary of
    - logic, algorithmic, systems, and network thinking
- Learn by the method of 知行合一
  - Unity of Knowledge and Action (UKA)
  - Mind-active and hands-on learning (动脑动手主动式学习)
    - Most bodies of knowledge are learned as UKA units
    - Aim at upper layers of Bloom's Taxonomy
    - Enable students to pass Knuth's Test

谢谢 Thank You

Q&A

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