An Introduction to Computer Science

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An Introduction to Computer Science

- Computer Science: What Is It and Why Study It?
- Computation: What Is It and Why Study It?
- Computability
- Computational Complexity
- Algorithms
- Data, Information, and Knowledge, and Their Representations
- Data Storage
- Computer Architecture
- Data Manipulation in Computer Systems
- Programming Languages and Compilers
- Operating Systems
- System Software and Application Software
- Software Engineering
- Knowledge Engineering and Artificial Intelligence
- Information Security Engineering

The Question: What Is Computer Science (CS) ?

What is Computer Science ?

Computer Science (CS): What Is It ?

♣ CS: What Is It?

- To answer the question "what is CS?", we have to consider the following more fundamental questions:
- What is science?
- What is a computer?
- This course will give you an answer to the second question.

♣ Notes

- "Computer Science" is a WRONG name as a discipline, from the viewpoints of either science or engineering.
- "Computation/Computing Science", "Computational Science", "Computer Engineering", "Computer Technology" are better names.

Computer Science (CS): A Debated Discipline (Name)

♣ Debate points

- "Is Computer Science Actually Science? Why or Why Not?"
- "Is the Discipline "Computer Science" a "Natural Science"?
- "Is Computer Science an Engineering Discipline?"
- "Computer Science: Is it Really a Science, and What's It a Science About? "
- "Computer Science Is Not a Science"
- "Computer Science Is Not Real Science"

♣ Notes

- "Computer Science and Technology" and "Computer Science and Engineering" show some ambiguity.
- Homework: Read the reading materials I sent you.

"Fields of Science and Technology" by UNESCO

- "Proposed International Standard Nomenclature for Fields of Science and Technology," UNESCO/ NS/ROU/257 rev.1, 1988.
- 11. Logic, 12. Mathematics
- 21. Astronomy and Astrophysics, 22. Physics, 23. Chemistry, 24. Life Sciences, 25. Earth and Space Science
- 31. Agricultural Sciences, 32. Medical Sciences, 33. Technological Sciences
- 1203. Computer Science
- 3304. Computer Technology

Science vs Engineering/Technology

- Science [The Oxford English Dictionary, 2nd Ed, OUP]
  - "The state or fact of knowing; knowledge or cognizance of something specified or implied; also, with wider reference, knowledge (more or less extensive) as a personal attribute."
  - "Contrasted or coupled with conscience, emphasizing the distinction to be drawn between theoretical perception of a truth and moral conviction."
  - "Knowledge acquired by study; acquaintance with or mastery of any department of learning. Also (a personis) various kinds of knowledge."
  - "A particular branch of knowledge or study; a recognized department of learning."

Science vs Engineering/Technology

- Science [The Oxford English Dictionary, 2nd Ed, OUP]
  - "In a more restricted sense: A branch of study which is concerned either with a connected body of demonstrated truths or with observed facts systematically classified and more or less colligated by being brought under general laws, and which includes trustworthy methods for the discovery of new truth within its own domain."
  - "The kind of knowledge or of intellectual activity of which the various 'sciences' are examples."
  - "In modern use, often treated as synonymous with 'Natural and Physical Science', and thus restricted to those branches of study that relate to the phenomena of the material universe and their laws, sometimes with implied exclusion of pure mathematics. This is now the dominant sense in ordinary use."

Science vs Engineering/Technology

- Scientific method [The Oxford English Dictionary, 2nd Ed, OUP]
  - "A method of procedure that has characterized natural science since the 17th century, consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses."
- Science [The Encyclopædia Britannica]
  - "Any system of knowledge that is concerned with the physical world and its phenomena and that entails unbiased observations and systematic experimentation. In general, a science involves a pursuit of knowledge covering general truths or the operations of fundamental laws."

Science vs Engineering/Technology

- Engineering [The Oxford English Dictionary, 2nd Ed, OUP]
  - "The action of the verb engineer; the work done by, or the profession of, an engineer."
  - "The art and science of the engineer's profession."
- Engineering [The Encyclopædia Britannica]
  - "The application of science to the optimum conversion of the resources of nature to the uses of humankind. The field has been defined by the Engineers Council for Professional Development, in the United States, as the creative application of 'scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behaviour under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property.'"

Science vs Engineering/Technology

- Technology [The Oxford English Dictionary, 2nd Ed, OUP]
  - "A discourse or treatise on an art or arts; the scientific study of the practical or industrial arts."
  - "Practical arts collectively."
  - "A particular practical or industrial art."
- Technology [The Encyclopædia Britannica]
  - "The application of scientific knowledge to the practical aims of human life or, as it is sometimes phrased, to the change and manipulation of the human environment."

Science vs Engineering/Technology

- Science
  - The state or fact of knowing or cognizing some class of things, i.e., objects or phenomena.
  - Unbiased observation, systematic experimentation, identification, description, experimental and theoretical investigation, explanation, prediction.
- Engineering
  - The application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems in order to make these artificial objects have desired properties and therefore function well.
- Technology
  - The application of scientific knowledge to the practical aims to solve a problem or serve some purpose.

Science vs Engineering/Technology

- ♣Science
  - What? (The goal is not necessarily explicitly defined) Why?
  - Discover, Observe, Investigate, Measure, Explain, Predict
  - New/Novel, Significant, Interesting, Credible, …
  - Scientists can enjoy playing "scientific games".
- ♣Engineering/Technology
  - For What? (The goal is necessarily explicitly defined) How?
  - Devise, Plan, Design, Development, Test, Evaluation
  - Useful, Reliable, Safe/Secure, Robust/Strong, Effective, Efficient, Inexpensive, Adaptive, …
  - It is not allowed for engineers to enjoy playing "engineering/technology games".

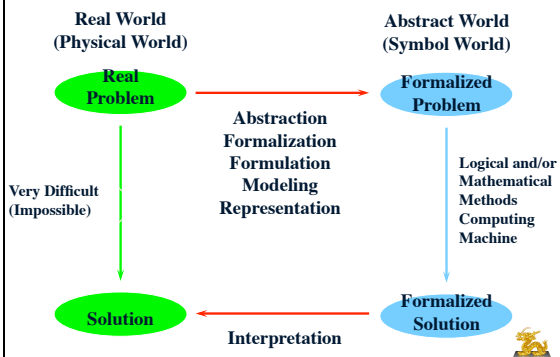
Science vs Engineering/Technology

- ♣Relationship between Science and Engineering/Technology
  - Science is the foundation to underlie engineering and/or technologies.
  - Engineering/Technologies encourage progress of sciences.

Science vs Art [P. J. Denning, CACM, 2005]

Science	Art
principles	practice
fundamental recurrences	skilled performance
explanation	action
discovery	invention
analysis	synthesis
dissection	construction

Real (Physical) World and Abstract (Symbol) World



Computer Science (CS): What Is It ?

- ♣Computer Science [The Oxford English Dictionary, 2nd Ed, OUP]
  - "The branch of knowledge that deals with the construction, operation, programming, and applications of computers."
- ♣Computer Science [The Encyclopædia Britannica]
  - "Study of computers, their design, and their uses for computation, data processing, and systems control, including design and development of computer hardware and software and programming."

Computer Science [BN-DCS-OUP-16]

- "The study of computer, their underlying principles and use. It comprises topics such as:
  - programming;
  - information structures;
  - software engineering;
  - programming languages;
  - compilers and operating systems;
  - hardware design and testing;
  - computer system architecture;
  - computer networks and distributed systems;
  - system analysis and design;
  - theories of information, systems, and computation;

Computer Science [BN-DCS-OUP-16]

- "The study of computer, their underlying principles and use. It comprises topics such as:
  - :
  - applicable mathematics and electronics;
  - computing techniques (e.g., graphics, simulation, artificial intelligence, and neural networks);
  - applications;
  - social, economic, organizational, political, legal, and historical aspects of computing."

Computer Science [BN-DCS-OUP-16]

- "It is not a science in the strict sense of being a discipline employing scientific method to explain phenomena in nature or society (though it has connections with physics, psychology, and behavioural science), but rather in the looser sense of being a systematic body of knowledge with a foundation of theory."
- "Since however it is ultimately concerned with practical problems concerning the design and construction of useful systems, within constraints of cost and acceptability, it is as much as a branch of engineering as it is a science."

Computing Discipline [DL-CS-16]

TABLE 1.2 Topic Areas of the Computing Discipline, 2001

Discrete Structures
Programming Fundamentals
Algorithms and Complexity
Architecture and Organization
Operating Systems
Net-Centric Computing
Programming Languages
Human-Computer Interaction
Graphics and Visual Computing
Intelligent Systems
Information Management
Social and Professional Issues
Software Engineering
Computational Science

Computer Science as a Discipline [P. J. Denning, 1999]

- "The discipline of computer science is the body of knowledge and practices used by computing professionals in their work."
- "The discipline of computer science was born in the early 1940s with the confluence of algorithm theory, mathematical logic, and the invention of the stored-program electronic computer. ….. By the early 1960s, there was a sufficient body of knowledge to merit the first academic departments and degree programs. This discipline is also called computer science and engineering, computing, and informatics."
- Notes: "The first departments of computer science were established in 1962 at Purdue and Stanford Universities. The first PhD in of computer science was awarded by the University of Pennsylvania in 1965. The curriculum effort in computer science was published by the ACM in 1968." [DL-CS-16]

Computer Science as a Discipline [P. J. Denning, 1999]

- "The body of knowledge of computing is frequently described as the systematic study of algorithmic processes that describe and transform information: their theory, analysis, design, efficiency, implementation, and application."

- **"The fundamental question underlying all of computing is, What can be (efficiently) automated?"**

Computer Science (CS): What Is NOT It ?

- ♣ CS is NOT just programming
  - Programming is only one of techniques among so many theories and techniques of CS.
- ♣ Computer scientists / software engineers are NOT programmers
  - A computer scientist / software engineer has a lot of work to do that are by far more than the work of a programmer.
- ♣ TCS is NOT pure mathematics as well as applied mathematics
  - Theoretical CS is just apply Logic and Discrete Mathematics to theories of computation.
  - Theoretical CS requires more actual/real consideration on applications than mathematics.

Computer Science among other Disciplines

Computational Mathematics, Computational Geometry, Computational Physics, Computational Mechanics, Computational Chemistry, Computational Biology, …

Embedded Systems, Robotics, Knowledge Engineering, Artificial Intelligence, Information Retrieval, Computer Vision, Computer Games, ...

System Software, Programming Methodologies, Programming Languages, Software Engineering

Database Systems, Computer Networks, Information Security Engineering, Computer Graphics, Natural Language Processing

Computation Theory, Information Theory, Concurrency, Formal Languages, Formal Semantics, Data Structure, Algorithm Theory

Computer Engineering, Communication Engineering

Logic, Mathematics, Physics, Electronics

The Question: Why Study Computer Science (CS) ?

Why Study Computer Science ?

Computer Science (CS): Why Study It ?

♣ It is indispensable, absolutely necessary

- In modern times, there is no discipline that does not invoke CS and can progresses without CS.
- In our daily life, ubiquitous computing is "to provide users with the way of computing anytime and anywhere such that one can use computing systems without even thinking about them". [Weiser, 1993]

♣ It is important

- Computational methodologies have become a major research methodology in almost all disciplines.
  - "Computational Logic", "Computational Mathematics", "Computational Geometry", "Computational Linguistics", "Computational Physics", "Computational Mechanics", "Computational Fluid-dynamics", "Computational Chemistry", "Computational Biology", "Computational Astronomy", "Computational Economics", ……

Computer Science (CS): Why Study It ?

♣ It is innovative

- Since its birth in 1950s, CS has been the most innovative and fastest growing discipline, and this will certainly continue in the 21st century.

♣ It is effective

- CS provided and will continuously provide effective ways to solve various problems in real world applications.

♣ It is efficient

- CS provided and will continuously provide high performance computing to satisfy efficiency requirements in real world applications.

♣ It provides jobs for you

- There are many various CS jobs for research, development, and management.

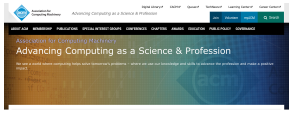
ACM A. M. Turing Award

ACM A. M. Turing Award

ACM: Association for Computing Machinery

♣ About ACM

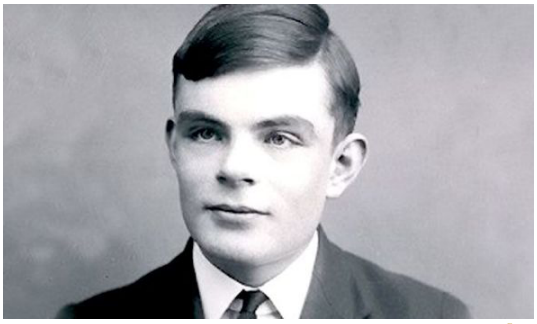
- ACM, the world's largest educational and scientific computing society, delivers resources that advance computing as a science and a profession. ACM provides the computing field's premier Digital Library and serves its members and the computing profession with leading-edge publications, conferences, and career resources.



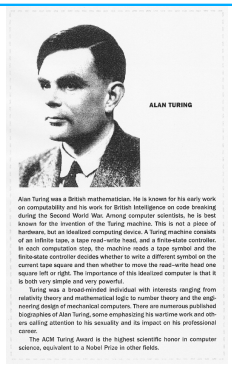
♣ ACM A. M. Turing Award

- The "Nobel Prize" in the computing world.

Alan Mathison Turing [1912.6.23 - 1954.6.7]



ACM A. M. Turing Award



ACM A. M. Turing Award

♣ACM A. M. Turing Award

- The "Nobel Prize" in the computing world.

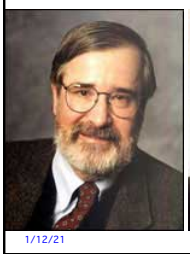
◆If you want to know the history of computer science, you do should know the winners of Turing Award and their contributions.

2000, Andrew Chi-Chih Yao (姚期智)

- **Citation: In recognition of his fundamental contributions to the theory of computation, including the complexity-based theory of pseudorandom number generation, cryptography, and communication complexity.**
- **Andrew Chi-Chih Yao (姚期智)**
  (Shanghai, China, December 24, 1946)
  is a Chinese computer scientist and computational theorist. He completed his undergraduate education in physics at the National Taiwan University, before completing a PhD in physics at Harvard University in 1972, and then a second PhD in computer science from the University of Illinois. He had been a Professor of Computer Science at Princeton University, where he continues to work on algorithms and complexity. In 2004, he became a Professor of Computer Science at Tsinghua University, Beijing, China.

2007, Edmund M. Clarke, E. Allen Emerson, and Joseph Sifakis

- **Citation: For their role in developing Model-Checking into a highly effective verification technology that is widely adopted in the hardware and software industries.**



2007, Edmund M. Clarke, E. Allen Emerson, and Joseph Sifakis

- **Edmund Melson Clarke, Jr.**
  (July 27, 1945)
  is an American computer scientist. He is the FORE Systems Professor of Computer Science at Carnegie Mellon University.

- **Ernest Allen Emerson**
  (Dallas, Texas, June 2, 1954)
  is a computer scientist and endowed professor at the University of Texas.

- **Joseph Sifakis**
  (Heraklion, Greece, December 26, 1946)
  is a Greek computer scientist with French citizenship.

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