CSE 211 (Theory of Computation)

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Adapted from slides by

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Theory of Computation

- Three areas of theory of computation
  - Automata
  - Computability
  - Complexity
- Linked by the question
  - What are the fundamental capabilities and limitations of computers?

Theory of Computation

- Automata
  - Automaton - a machine made in imitation of a human being
  - DFA, NFA
  - Context-free grammar (CFG), pushdown automata (PDA)
- Computability
  - Decidability
  - What can or cannot be solved
- Complexity
  - Tractability
  - What can or cannot be solved “efficiently”
  - Time complexity: P, NP, NP-complete, NP-hard
  - Space complexity: PSPACE

Theory of Computation

> “Computer science is no more about computers than astronomy is about telescopes. ”
>
> — Edsger W. Dijkstra

Theory of Computation

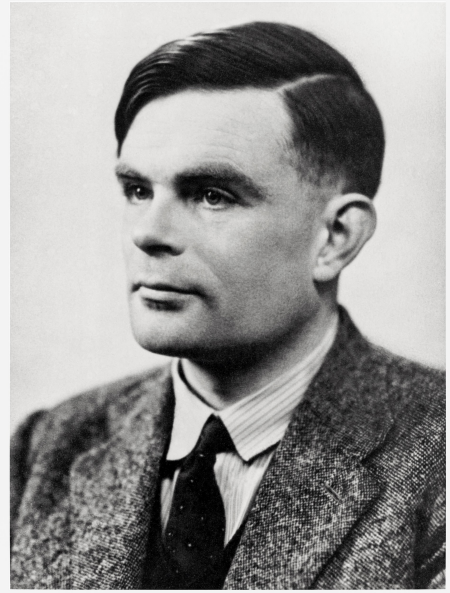
- Computation and computability
  - Building fast vehicles vs can we exceed the speed of light?
  - Building efficient engines vs can we build a perpetual motion machine?

Models of Computation

- Finite Automata
  - DFA, NFA
  - Limited amount of memory
  - Applications in compilers, control units of hardware, etc.
- Context-free grammar
  - More expressive than finite automata
  - Applications in compilers, AI and many other areas
- Turing Machine
  - Even more powerful
  - Can simulate a computer!
  - Problems Turing machine cannot solve are beyond theoretical limits of computation

Alan Turing

- “father of theoretical computer science and artificial intelligence” - wiki
- Proposed Turing machines
  - A general model of computation
  - Can simulate a computer
- Helped break the Enigma code during WW II
- Proposed the Turing test for AI
  - Distinguishing humans and computers through interrogation



Syllabus

- Regular languages
  - Regular expressions
- Finite automata
  - Deterministic finite automata (DFA)
  - Nondeterministic finite automata (NFA)
- Context-free languages
  - Context free grammars (CFG)
  - Pushdown automata (PDA)
- Turing machines
  - Equivalence with a computer
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  - Time and space complexity

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Regular Languages

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  - Languages recognized by finite automata - DFA, NFA
  - Languages described by regular expressions
- Limitations
  - Finite number of states
  - Hence finite amount of memory
- An example of a non-regular language

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Context-Free Languages

- Context-Free Languages
  - Languages described by context-free grammars (CFG)
  - Languages recognized by pushdown automata (PDA)
- Extensively used in compilers (parsers)
- First used in study of human languages

An Informal Example

- Language of palindromes
- Palindrome
  - A string that reads the same backward and forward
  - 0110, 11011, ϵ
- Recursive definition for palindromes (over binary alphabet)
  - 0, 1 and ϵ are palindromes
  - if w is a palindrome, then $0w0$ and $1w1$ are palindromes

An Informal Example

aibohphobia

- The word used for the *fear of palindromes*. The word *aibohphobia* is itself a palindrome
- `https://www.urbandictionary.com/define.php?term=aibohphobia`

An Informal Example

- A CFG for palindromes
  - $P \rightarrow \epsilon$
  - $P \rightarrow 0$
  - $P \rightarrow 1$
  - $P \rightarrow 0P0$
  - $P \rightarrow 1P1$

Exercise

- Design a CFG for the language

$$\{0^n 1^n | n \geq 0\}$$

  - ϵ
  - 01
  - 0011
  - 000111
  - ...

CFG for $\{0^n1^n|n \geq 0\}$

- A CFG for the language $\{0^n1^n|n \geq 0\}$
  - $A \rightarrow \epsilon$
  - $A \rightarrow 0A1$

Logistics

- Email
  - zaman.tanjeemazwad@gmail.com
- Textbook
  - J. E. Hopcroft, R. Motwani, and J. D. Ullman, ***Introduction to Automata Theory, Languages, and Computation***
- Reference books
  - M. Sipser, ***Introduction to the Theory of Computation***
  - H. R. Lewis and C. H. Papadimitriou, ***Elements of the Theory of Computation***