

Before Starting

- Questions
- Computational problems as sets
 - Need to know the answer in advance?
 - Representing the relation between inputs and the problem schematically?

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Unit A3: Overview

- Discuss your ideas about “Theory of Computation”
- Preview the main components of the Theory of Computation
- Practice representing computational problems as sets
- Preview Exercise A3 “Computational problem solving”

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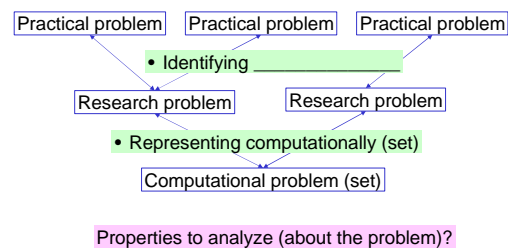
Exercise A1 Part 1

- Your ideas about Theory of Computation
 - Task 1 (review): Identify/analyze CS “theories” you know
 - Task 2 (~ Group Exercise 3): Usefulness of the theories you know; missing elements

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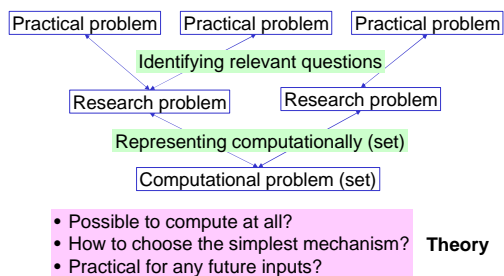
Problems and Theory



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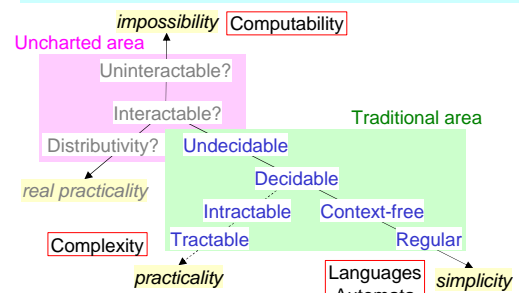
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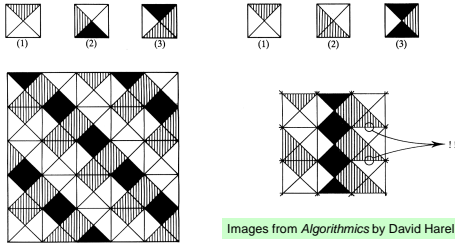
Preview: Theory of Computation



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Example 1: Floor Tiling



Images from *Algorithmics* by David Harel

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Cf. some of your own problems

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Computability

- Content Goal 4
- Example questions
 - What are the limitations of computation? All the computational problems (sets) solvable?
 - How can we compare different forms of “computation?”
 - What is the notion of “computation?”
- Significance?
- Are your own problems “computable?”

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Schematic representation 8

Example 2: Survivor

- Scenario
 - Alone on a large island where you survived an aircraft crash.
 - Established a base where you can spend your nights safely.
 - Still need to explore the island to obtain foods.
- Appropriate (minimal) mechanism for your “mental” computer?

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Languages/Automata

- Content Goal 5
- Example questions
 - Where are the balance between the simplicity of computational mechanisms and their abilities?
 - How can we identify an appropriate computational mechanism for a given problem (set).
- Significance?
- The simplest mechanism for your own problems?

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Example 3: Scheduling

- How to define the problem?
- Must be sufficiently general to be able to handle cases including:
 - Your time management
 - Organizing a team of workers
 - Assigning courses to instructors
 - Schedule the analysis process for the entire human genome

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Cf. some of your own problems

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Complexity

- Content Goal 6
- Example questions
 - How does the input data size affect the computation?
 - What would be the limit of “practical” computation?
- Significance?
- Practicality of your own problems, esp. facing large data?

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What is not usually discussed...

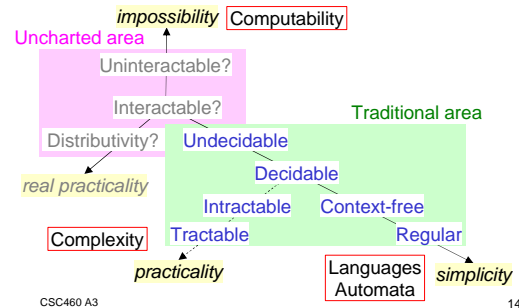
- Content Goal 3: Interactivity
- Example questions
 - How well does algorithmic computation fare in real-world computation?
 - What are the essential properties that are needed to solve real-world problems computationally?
- Significance? Examples? Implications?

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These questions as computational problems?

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Preview: Theory of Computation



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Interim Summary

- Theory of Computation
 - Offers principles in three main aspects: computability, languages/automata, complexity, most commonly dealing with problems as sets
 - Limitations due to its traditional foundation on algorithmic computation, cf. interactivity
- Caveat
 - Focus on computational problems (sets), i.e., no systematic methods for problem transformation, cf. discrete math

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Practice: Robotics

- Suppose that **robotic control of an automobile** has been transformed into a computational problem (set).
- Analyze with respect to the following:
 - Computability (possibility)
 - Languages/Automata (simplest mechanism)
 - Complexity (practicality with respect to the input size)

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Group Exercise 1

- Suppose that a **typical compilation problem** has been transformed into a computational problem (set).
- Analyze with respect to the following:
 - Computability (possibility)
 - Languages/Automata (simplest mechanism)
 - Complexity (practicality with respect to the input size)

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Set Representation of Problems

- Benefits
 - To analyze/compute such problems, we only need a **single mechanism** to check set membership
 - Well-developed techniques in **mathematics** are available
- Limitations?

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Alternative Forms

- Computational problem
- Set
- Language
 - Set of strings (special case of set)
- Characteristic function
 - Outputs yes/no, i.e., comparable to a relation (set of tuples)

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Set Examples

1. What is the sex of Furby?
{*female*}
2. What are palindromes?
{*a, cc, wow, abba, kayak, hannah, ...*}
3. Addition operation (on natural numbers)
{(0, 0, 0), (0, 1, 1), (1, 0, 1), (1, 1, 2), ...}
4. Causal relation (on any possible event)
{(*drink, joy*), (*drink, nausea*), (*drink, addiction*), ...}

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Not knowing answers; Avoiding "..."

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Set Notation (Review)

- List notation (technically, only for finite sets)
 - {1, 2, 3, 4, 5}
 - {paper, stone}, (scissors, paper), (stone, scissors)}
- Predicate notation
 - { $x \mid 0 < x \leq 5, x$ is a natural number}
 - {(x, y) | x wins over y in the paper-scissors-stone game}
 - { $x \mid x$ is a number never used by the human}

Predicate notation as a filter

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Practice: Predicate Notation

- Palindromes
{*a, cc, wow, abba, kayak, hannah, ...*}
= { $x \mid x$ is a palindrome} **A better way?**
= { }
- Addition operation (on natural numbers)
{(0, 0, 0), (0, 1, 1), (1, 0, 1), (1, 1, 2), ...}
= { }
- Causal relation (on any possible event)
{(*drink, joy*), (*drink, nausea*), (*drink, addiction*), ...}
= { }

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Group Exercise 2

- Infinite loop is one of the most common bugs in any program. It would be enormously helpful if someone writes a program to detect infinite loops in a given program. **Give** the set representation of the computational problem involved here. **Speculate** the basic Theory properties (i.e., possibility, etc.), referring to the set (a concise, informal description suffices).

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Group Exercise 3

- For any (possibly very large) academic department, how can we assign all the courses to the instructors within the usual constraints (e.g., a single instructor for a single course)? **Give** the set representation of the computational problem involved here. **Speculate** the basic Theory properties, referring to the set.

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Unit Summary

- Theory of Computation: computability, languages/automata, complexity
- Set representation of computational problems: list/predicate notations
- Understand Unit A3 Exercise
- Summary question
 - We discussed broad ideas with little details.
So, you must have questions or be uncertain on at least some aspect. What are they?