Example Problems

- Search
- Finding the max
- Summation
- Matrix multiplication $c_{ij} = \sum_{k=1}^{n} a_{ik} b_{kj} \quad \text{for } 1 \le i, j \le n$
- Merging
- Merge sort

Handling conflicts
[C: common, E: exclusive
- EREW [not realistic]
- CREW
- CRCW
  - Common write
  - Priority write

Class NC "Nick's class"

- Informally, efficiently parallelizable class of problems
- Definition: Solvable on a PRAM in log time with polynomially-many processors
- NC $\subseteq$ LogSPACE $\subseteq$ P
- Examples?

Meaning of this?
Example of P problem not in NC?

D4 Unit Summary

- Parallel processing can affect complexity, and Chomsky hierarchy, but not computability.
  - Some (not all) common problems have exponential speed up with parallel processing.
- The complexity of distributed computing in general is more difficult to analysis.

Unit D5: Overview

- What's wrong with TM or TM-based Theory of Computation?
  - Reading: MacLennan
  - More examples
  - Analyzing the source of the problem
- Preview Exercise D5 "Reading: Super-Turing Thesis"

Question

- Is the Theory of Computation relevant to all the real-world computational problems?
- Why or why not?

Group Exercise 1

- Compare your exercises (reading MacLennan)
- Prepare to present interesting points (possibly including similarities and differences)

Reading: MacLennan (1)

1. What is the main research question of the paper?
2. What is the significance of the research question?
3. Does the paper respond to the research question well?
4. Is the paper organized well?
5. Summarize the author's criticism of the traditional Theory of Computation *in the order of importance* (as you understand).
6. Try to criticize the author's position/arguments. If you cannot do this, explain why.
7. How would the author's criticism about the traditional Theory of Computation affect your analyses of your own problems and/or your choice of the mini research problems that have been done so far, *focusing on computability and (time) complexity*?

Reading: MacLennan (2)

8. [Optional] What would the author mean by "pitfalls of learning"? (in the middle of p. 19)
9. [Optional] Discuss whether you would analyze yourself in terms of a Turing machine or a natural computation, referring to the arguments in the paper and relevant properties of yours.
10. [Optional] The author does not directly discuss one subarea, formal languages/automata (except the TM). Speculate what the author would say about the Chomsky hierarchy.
11. [Optional] Speculate on how to define the "power" of natural computation. (in the middle of p. 19)

Where is This Community?

Social classes

- Within each colony, there is a strict division of labor. Some are warriors who defend their colony. The farmers collect leaves, and the domestic workers tend the mushroom beds and the young.

Job description

- Farmers collect leaves. Well-worn trails are made as they travel to and from their colony. They are selective about the leaves they collect, and will often travel a long distance to find a certain plant. In this way, they spread out their consumption so that trees do not become stripped.
- In special chambers, domestic workers process the leaves into a pulp, making a bed of fertilizer upon which mushrooms are grown. They carefully weed the mushroom bed, ensuring that only one kind of mushroom is grown, and they continually add additional leaves to enrich the crop.

Swarm Intelligence

- Are ants intelligent?
- Is intelligence in the brain?

Where is This Community?

- The entire community consists of the near-blind, due to some genetic problem.
- This community survived many years, even against the attacks of invaders.

Army Ants

- Successful for millions of years.
- How could they function?
  - E.g., how could they find food?

Swarm Intelligence

- Each ant is not very intelligent.
- Their colonies exhibit complexity approaching that of intelligence.
- The intelligence is in the colonies, possibly including the environment.
  - Cf. the shortest path recorded in the environment (not known by each ant)

cf. Chinese room (Searle)

cf. Mass Stupidity

Group Exercise 2

- The Irishmen in the area (say, 100 of them) like to go to the local pub when Irish music is played (Thursday evenings) only if the pub is not crowded (say, up to 60 people).

How could they predict the pub is not crowded?

El Farol Problem

- Example attempts
  - Same as the last week
  - Average of the last four weeks
  - Trend in the last eight weeks
- If they can all predict, all of them would go and the pub will be crowded. False prediction
- There is no absolute way to predict the crowdedness of the pub. Implications?

Can a TM design this?

AI problems?

Challenges in/around CS

- Operating System
  - Interprocess communication, I/O, memory
- Software Engineering
  - Specification, verification Doomed to failure?
- AI
  - Games, robotics, NLP, Cyc, 5th Generation AI
- Cognitive Science
  - Theory of mind (cf. Fodor: mind as TM)

Group Exercise 3

- What would be the essential properties that might make TM inappropriate for modeling the real-world (or computation in general)?

Observation

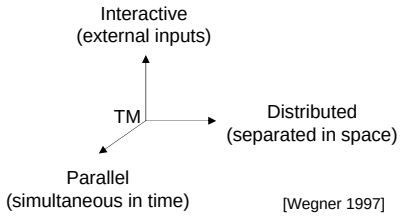
- The environment (context) changes over time.
  - No control over adversaries.
  - Future environment is unknown/unpredictable.
- The environment may affect agents (including their thinking process) through interaction.
  - Nonmonotonic (e.g., belief change)
- TMs cannot handle the passage of time.
- TM learning is not impossible, but impractical.
- Tentative conclusion: Interaction is non-TM-recognizable.

Algorithm vs. Interaction

Algorithm	Interaction
Closed-book exam	Open-book exam
Sales contracts	Marriage contracts
Rationalism	Empiricism
Compositional	Non-compositional
Reductionistic	Holistic
Monotonic	Non-monotonic
TM	must be something...

We find parallel algorithms and distributed algorithms, but no interactive algorithms.

Elements of Modern Computing



[Wegner 1997]

Effects on "Theory"?

Paradigm Shift

- Astronomy: Ptolemaic → Copernican
- Physics: Classic → Relativistic
- Mathematics:
  - Hilbert's program → Gödel's incompleteness
- Linguistics
  - Transformational → Mildly Context-Sensitive
- Psychology
  - Behaviorism/cognitivism → Social/cultural

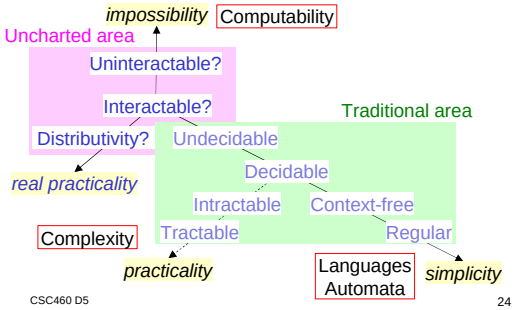
Computer Science?

Computer Science

- "goto" considered harmful: Structured programming
- "assignment" considered harmful: Functional programming
- "procedure" considered harmful: Logic programming, object-oriented programming
- Too much of the TM-based "theory" considered harmful: model of interaction

Turing and von Neumann hinted models beyond TM.

Extended Theory of Computation



Unit Summary

- TMs are too limited as a model of "real" computation.
  - Call for a more realistic model
- The future of Computer Science may depend on a paradigm shift from the current TM-based theory to a new theory of interaction.
  - The current "Theory of Computation" hopefully provides useful information for this transformation.
- It might even be the theory of "everything," cf. Unified Theory in physics. But feasible?

Summary Question

- What would a more realistic model of computation look like? Speculate.
- Questions/Comments/Suggestions

References available on-line