Aalto University
School of Science

CS-C2160 Theory of Computation

Introduction and Practical Arrangements

Pekka Orponen
Aalto University
Department of Computer Science

Spring 2021

What is Theory of Computation?

Theory of Computation

- The mathematical theory of fundamental computational models – their power, limitations and representations.
- Constitutes the basic mathematical framework for designing and understanding computational systems *exactly* and *generally*, *independent of implementation*.

- Commonly grouped into three strongly interrelated areas:
  - *Automata theory:* Models and characterisations of “simple” computational systems.
    - Key developments: S. Kleene (1950’s), R. Büchi, S. Ginsburg, M. Rabin, A. Salomaa, M. Schützenberger et al. (1960’s).
    - Applications: finite-state communication and computation protocols, string processing, pattern matching.
  - *Formal languages and grammars:* Representations of structure in strings (“words”, “sentences”).
    - Key developments: N. Chomsky (1950’s), S. Ginsburg, S. Greibach, M. Harrison, A. Salomaa, M. Schützenberger et al. (1960’s).
    - Applications: Programming language compilers, natural language processing.
  - *Computability theory:* Models, power and limitations of “universal” computational systems.
    - Key developments: A. Turing, K. Gödel, A. Church, E. Post (1930’s); S. Kleene, A. Markov (1950’s).
    - Applications: Understanding the ultimate limits of computation, recognising possibilities for universal computation in natural and artificial systems (e.g. biology, physics).
    - Strong connections to mathematical logic, further developments in that direction under the name "Recursion Theory".

- Subfield of the broader area of *Theoretical Computer Science*:
  - Mathematical concepts and methods for modelling and analysing computing systems and for designing efficient solutions for computational problems.
- Other subfields of Theoretical Computer Science:
  - *Computational complexity theory:* The theory of feasible ("practical") computation (J. Hartmanis, R. Stearns (1960's); S. Cook, L. Levin, R. Karp (1970's); C. Papadimitriou, M. Sipser, J. Håstad, A. Razborov etc. (1980's –)).
  - *Program correctness and verification*: Mathematically precise ways of defining computing systems and verifying the correctness of their behaviour (E. Dijkstra, A. Hoare (1960's); R. Manna, A. Pnueli, D. Scott etc. (1970's–)).
  - *Design and analysis of algorithms* (D. Knuth, J. Hopcroft, R. Tarjan etc.)
  - *Cryptology* (R. Rivest, A. Shamir, L. Adleman etc.)
  - *Theory of parallel and distributed systems* (L. Lamport, N. Lynch, R. Milner, L. Valiant etc.)
  - *Machine learning theory* (L. Valiant (1984) etc.)
  - *Quantum computing theory* (P. Shor (1994) etc.)

Practical Arrangements

Registration, teaching, webpage

Registration: Obligatory, by OODI, deadline Jan 26, 2021.

Lectures: Tuesdays 10–12 on Zoom, in English by Pekka Orponen

Lectures will be pre-recorded and made available via MyCourses.

Tutorials: Not obligatory but highly recommended! Plus you earn bonus exam points!

- Tuesdays 16–18 Zoom, **from 12 Jan**
- Wednesdays 10–12 Zoom, **from 13 Jan**
- Wednesdays 12–14 Zoom, **from 13 Jan**
- Thursdays 12–14 Zoom, **from 14 Jan**
- Fridays 10–12 Zoom, **from 15 Jan**

Computerised home assignments: Obligatory and personalised.

Available soon, announced on MyCourses.

Course links:

MyCourses:
`https://mycourses.aalto.fi/course/view.php?id=28164`
Zoom: `https://aalto.zoom.us/j/66313829636`
Zulip: `https://cs-c2160.zulip.cs.aalto.fi`

To pass the course, you need to...

1. Pass the computerised assignments *before taking the exam*.

   Otherwise your exam will not be graded.
2. *After passing the computer exercises*, take an exam (next exam Wed 14 Apr 2021, more in Summer and Autumn 2021).
3. Maximum number of points on exam is 60.
   Grade limits may vary by exam but
   - with 30 points, grade 1 is guaranteed, and
   - with 54 points, grade 5 is guaranteed.
4. There are 3 homework problems each week. By doing these, you gain bonus points for exams according to the table (1 for every 5 problems):

#solved:	0–4	5–9	10–14	15–19	20–24	25–29	30-33
bonus:	$+0$	$+1$	$+2$	$+3$	$+4$	$+5$	$+6$

5. In addition, you earn one extra bonus point by filling in the feedback questionnaire at the end of the course.

Bonus points are valid in all exams in 2021.

Weekly tutorials

Teaching asssistants helping you:

- Sander Aarts
- Siiri Kuoppala
- Trang Nguyen

Procedure to learn (and get bonus points):

1. solve the homework problems and prepare notes on your solutions
2. attend a tutorial session and mark the problems you have solved as “done”
3. (when requested) explain your solution to other students on ~~whiteboard~~ Zoom, by e.g. sharing your notes via camera

Returning homework solutions by email is unfortunately *not* possible.

Before covering the homework problems, each session begins with a few *ex tempore*, no-credit classroom problems that review the lecture material from the same week. (NB. Hence the sessions begin already in the first lecture week, with only classroom problems for discussion.)

Material

On MyCourses

- Lecture slides
- Typeset lecture notes (in Finnish)
- Example homework/exam problems with solutions
- Solutions to weekly non-credit ”Supplementary exercises”
- Plus some other hopefully helpful stuff

Recommended supporting textbook

Michael Sipser, Introduction to the Theory of Computation (3rd Edition), 2013.