THEORETICAL COMPUTER SCIENCE
W2019

VERA FISCHER

This is a master level course in theoretical computer science. We will cover central topics in recursion theory and computational complexity. **The lectures are taking place Thursdays from 9:00 to 11:20 at the Seminar room of the KGRC.** The final exam will be oral.

Detailed information on the material covered during the semester, including relevant references to the literature, will be regularly given here. Our two main textbooks are listed below. Both of those textbooks are available for **free download** via the **University of Vienna Library**. The book of Herbert Enderton, *Computability theory. An introduction to recursion theory*, gives a detailed introduction to the subject of recursion theory and will be used in the beginning of the course. The book of Sanjeev Arora and Boaz Barak, *Computational complexity. A Modern Approach*, gives a comprehensive account of many interesting topics in computational complexity. Another excellent source is [3].

Dates for the final exam are 30.01.2020 and 31.01.2020. If you would like to take the final exam in one of those two dates, please send me an E-mail a couple of days in advance.

Lecture 1, 3.10.: We defined the classes of primitive recursive and general recursive functions. The notions of register machine, as well as function computable by a register machine were defined. Most of the material can be found in Sections 1.2 and 2.1 of [1].

Lecture 2, 10.10.: We proved that every register machine computable function is general recursive and considered the memory and location functions describing the computation of a register machine. The material can be found in Sections 3.1 and 3.2 of [1].

Lecture 3, 17.10.: In the lecture, we introduced the notion of recursive enumerability, proved the Theorem of Kleene and showed that a partial function is computable if and only if its graph is a recursively enumerable relation.

Lecture 4, 31.10.: There were two main theorems proved in the lecture: the Parameter Theorem and the Theorem of Rice. The material can be found in Chapter 4 of [1].

Lecture 5, 07.11.: The lecture covers chapter 5 of [1].

Lecture 6, 14.11.: Turing degrees and the jump operation. The material corresponds to Chapter 6 of [1].

Lecture 7, 21.11.: Turing machines, configuration graph, robustness.

Lecture 8, 28.11.: Computation tables; time complexity; simulating a k-tape Turing machine with a single tape Turing machine; polynomial time universal Turing machine; time hierarchy theorem; non-deterministic Turing machines.

Lecture 9, 05.12.: Deterministic vs non-deterministic time TM; non-deterministic time complexity classes; alternative characterization of $\mathbb{NP}$; space complexity; space complexity classes; space hierarchy theorem; relations between cmplexity classes;

Lecture 10, 12.12.: Theorem of Savitch; Reductions and Completeness; SAT, CIRCUIT SAT; CIRCUIT SAT is reducible to SAT; Hamilton Path is reducible to SAT;

Lecture 11, 09.01. PATH is reducible to CIRCUIT SAT; Composition of reductions; CIRCUIT VALUE is $\mathbb{P}$ complete; Cook's theorem; Complements of non-deterministic classes;

Lecture 12, 16.01 Theorem of Immerman-Szelepscényi; $\mathbb{N}\mathrm{SPACE}(f(n)) = \mathrm{co}\mathbb{N}\mathrm{SPACE}(f(n))$; PRIMES; The Hierarchy Theorem; First Theorem of Gödel of Incompleteness.

References

[1] H. Enderton *Computability theory. An introduction to recursion theory.* Elsevier/Academic Press, Amsterdam, 2011. xii+174 pp. ISBN: 978-0-12-384958-8.
[2] S. Arora, B. Barak *Computational complexity. A Modern Approach.* Cambridge University Press, Cambridge, 2009. xxiv+579 pp. ISBN: 978-0-521-42426-4.
[3] C. H. Papadimitriou *Computational complexity.* Addison-Wesley Publishing Company, Reading, MA, 1994. xvi+523 pp. ISBN: 0-201-53082-1
[4] M. Ziegler *Mathematische Logik.* Mathematik Kompakt. Birkhäuser Verlag, Basel, 2010. viii+116 pp. ISBN: 978-3-7643-9973-3

Institut für Mathematik, Kurt Gödel Research Center, Augasse 2-6, UZA 1 - Building 2, 1090 Vienna, Austria
Email address: `vera.fischer@univie.ac.at`