Foundations of Theory of Computation (22-772, Spring 2020)

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Level: Graduate

Prerequisites: Formal languages (an undergraduate course)

Course description: The main objective of this course is to present in detail the basic concepts and facts in *theory of computation*. Our basic goal will be to convince the audience that an algorithm is a *finitely presentable discrete dynamical system with local property*. Actually, most of the contents, containing the details of the Chomsky hierarchy, may be considered as case-studies for this aim.

The course starts with a general view of theory of computation, emphasizing on main concepts, and without reference to any specific model. To do this, we start with yes/no problem-types along with the corresponding *natural* classes of languages (in the sense of Church-Turing thesis), and will develop a model-free setup that will cover most of what will be discussed in the sequel. Then we start with the concept of an automaton as a unary algebra and will prove most basic facts about this model. Then DFA's are discussed as finite automata with output, giving rise to the theory of regular languages. We will continue with the Chomsky hierarchy containing PDA's, DPDA's, LBA's, and Turing machines, discussing most important properties of CF, CS and r.e. languages in detail.

Then we will concentrate on function problems, discussing most basic facts from recursion theory. In this, there will be a juxtaposition of facts from this and the previous part, making sure that the students understand the basic intuitions (say the concepts of *a reduction* and that of *s.m.n-Theorem*). This part will go up to the recursion theorem and its counterpart for languages.

Selected topics will be discussed according to the interest of students and time limitations. Such topics could be among, but not limited to, the following list:

Selected topics: Coalgebras & computation, randomized algorithms, quantum computation, cellular automata, computational complexity.

Evaluation: The final grade is based on a regular final exam and a take-home exam.

References: The course is not based solely on the following references, but they may give you a general idea about the contents of this course.

References

[1] D.S. Bridges. *Computability: A Mathematical Sketchbook.* Graduate Texts in Mathematics. Springer New York, 1994.

[2] D.A. Simovici and R.L. Tenney. *Theory of Formal Languages with Applications.* World Scientific, 1999.