UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Theory of Computation

2425-1-F1801Q132-F1801Q133M

Aims

The course of Theory of Computation aims to provide students with the theoretical tools to understand the computational complexity of problems, how they are classified based on their complexity, and the methodologies to solve them, either exactly or with demonstrable approximation performance. It also introduces algorithmic methodologies and advanced data structures to tackle fundamental problems on large texts.

In more detail, the objectives are:

- To understand the fundamental concepts of the main model of computation (Turing Machine) and its variants.
- To understand which problems can be solved by a computer (decidability) and which cannot be solved in a reasonable time (intractability).
- To learn how a problem can be reduced to another to demonstrate the relative complexity of problems.
- To learn to classify problems based on their computational complexity (e.g., P, NP, NP-complete).
- To understand approximation algorithms, i.e., algorithms that obtain a solution demonstrably close to the optimum in reasonable time for problems that are intractable to solve exactly.
- To understand parameterized algorithms, i.e., algorithms that allow exact solutions to some intractable problems by limiting the exponential growth of their solving algorithms' computation time to a parameter of the instance that is of limited value in practical cases.

The course also aims to introduce the student to the theoretical foundations and practical applications of:

- Exact and approximate string matching
- Data structures for string indexing

Contents

Basic concepts of theory of computation: Turing machines, decidability, and intractability of computational problems. Reductions between computational problems and classification of problems based on computational complexity. Approximation and parametric complexity. String matching algorithms. Indexing structures.

Detailed program

1. Basic concepts of theory of computation:

- The Turing Machine model of computation and its equivalence with its main variants (multitape machines, non-binary alphabet, nondeterministic machines)
- Relationships between formal languages and computational problems
- Limits of computability: undecidability of the Halting Problem

2. Tractability and intractability, i.e., classification of problems based on computational complexity:

- Decidability in polynomial time on deterministic machines (P, coP) and on nondeterministic machines (NP, coNP)
- Equivalence of nondeterministic polynomial-time decidability and deterministic polynomial-time verifiability
- Polynomial reductions between decision problems
- NP-completeness of the Satisfiability Problem (SAT)
- Proofs of NP-hardness and NP-completeness

3. Approximation complexity
4. Parameterized algorithms
5. Exact string matching algorithms

- Finite state automaton
- Knuth-Morris-Pratt algorithm
- Algorithm based on the shift-and paradigm

6. Approximate string matching algorithms

- Algorithm based on the shift-and paradigm

7. Text indexing structures

- Suffix Array
- Burrows-Wheeler Transform
- FM-index

Prerequisites

Basic concepts of formal languages. Basic concepts of algorithms and data structures.

Teaching form

Lectures and classroom exercises.

All activities are conducted in person and are not recorded or streamed.
Teaching is delivered in Italian.

There are 27 lectures of 2 hours each, conducted in a lecturing format initially and then in an interactive format.

Textbook and teaching resource

Slides and written notes.
Book: Sipser, Michael. Introduction to theory of computation.

Semester

First semester.

Assessment method

The assessment of learning consists of a written exam.

The written exam is based on open-ended questions related to the concepts and techniques presented in the course, as well as exercises requiring the application of the learnt concepts and techniques.

The written exam is evaluated based on the correctness and completeness of the answers.

Two mid-term written exams are scheduled.

Office hours

Office hours are by appointment to be arranged with the instructors.

Sustainable Development Goals