09M31CI423: Advanced Theory of Computation

Course Credit: 3
Semester: M.Tech, III

Introduction

This course introduces the theory of computation through a set of abstract machines that serve as models for computation - finite automata, pushdown automata, and Turing machines and examines the relationship between these automata and formal languages. Additional Topics beyond the automata classes themselves include deterministic and nondeterministic machines, regular expressions, context free grammars, undecidability, and the P = NP question.

Course Objectives (Post-conditions)

Knowledge objectives:

1. You will learn regular languages and finite automata.
2. You will learn context-free languages, push-down automata, and Turing recognizable languages.
3. Be exposed to a broad overview of the theoretical foundations of computer science.
4. Be familiar with thinking analytically and intuitively for problem-solving situations in related areas of theory in computer science.

Application objectives:

Design a compiler from scratch using concepts taught in the class.

Expected Student Background (Preconditions)

Graduate level courses in algorithms and complexity of algorithms are desirable.

Topics Outline:

S NO	Topics	Hrs
1	• Introduction: Scope of study as limits to compubality and tractability. • Why it suffices to consider only decision problems, equivalently, set membership problems. Notion of a formal language.	1
	• DFAs and notion for their acceptance, informal and then formal definitions. Class of regular languages. • Closure of the class under complementation, union and intersection. Strategy for designing DFAs.	3
	• Pumping lemma for regular languages. Its use as an adversarial game. • Generalized version. Converses of lemmas do not hold.	2
	• NFAs. Notion of computation trees. Definition of languages accepted. Construction of equivalent DFAs of NFAs. NFAs with epsilon transitions. Guess and check paradigm for design of NFAs.	4
	• Regular expressions. Proof that they capture precisely class of regular languages. Closure properties of and decision problems for regular languages.	3
	• Myhill-Nerode theorem as characterization of regular languages.States minimization of DFAs.	2
2	• Notion of grammars and languages generated by grammars.	2

	Equivalence of regular grammars and finite automata. Context free grammars and their parse trees. Context free languages. Ambiguity.	
	• Pushdown automata (PDAs): deterministic and nondeterministic. Instantaneous descriptions of PDAs.Language acceptance by final states and by empty stack. Equivalence of these two.	2
	• PDAs and CFGs capture precisely the same language class.	1
	• Elimination of useless symbols, epsilon productions, unit productions from CFGs. Chomsky normal form.	2
	• Pumping lemma for CFLs and its use. Closure properties of CFLs. Decision problems for CFLs.	3
3	• Informal proofs that some computational problems cannot be solved.	1
	• Turing machines (TMs), their instantaneous descriptions. Language acceptance by TMs. Hennie convention for TM transition diagrams.Robustness of the model-- equivalence of natural generalizations as well as restrictions equivalent to basic model. Church-Turing hypothesis and its foundational implications.	5
	• Codes for TMs. Recursively enumerable (r.e.) and recursive languages. Existence of non-r.e. languages. Notion of undecidable problems. Universal language and universal TM. Separation of recursive and r.e. classes. Notion of reduction. Some undecidable problems of TMs. Rice's theorem.	5
	• Undecidability of Post's correspondence problem (PCP), some simple applications of undecidability of PCP.	3
4	• Notion of tractability/feasibility. The classes NP and co-NP, their importance. Polynomial time many-one reduction. • Completeness under this reduction. Cook-Levin theorem: NP-completeness of propositional satisfiability, other variants of satisfiability. • NP-complete problems from other domains: graphs (clique, vertex cover, independent sets, Hamiltonian cycle), number problem (partition), set cover.	6
	Total	45

References

1. Elements of the Theory of Computation. Harry Lewis, Christos H. Papadimitriou, Second Edition, Pearson Education, 1998.
2. John E. Hopcroft, Rajeev Motwani and Jeffery D. Ullman, Automata Theory, Languages, and Computation (3rd. Edition), Pearson Education, 2008.
3. Michael Sipser, Introduction to the Theory of Computation, Books/Cole Thomson Learning, 2001.

4. JE Hopcroft and JD Ullman, Introduction to Automata Theory, Languages, and Computation, Addison-Wesley, 1979
5. K.Krithivasan and R.Rama; Introduction to Formal Languages, Automata Theory and Computation; Pearson Education, 2009
6. http://nptel.ac.in/

Evaluation Scheme:

S.No	Examination	Marks
1	T-1	15
2	T-2	25
3	T-3	35
4	*Internal Marks	25

*Internal Marks Breakdown:

Assignments 9 marks (3x3)

Quizzes 12 marks (3x4)

Regularity 4 Marks