New Jersey Institute of Technology
Ying Wu College of Computing
Department of Computer Science
CS 341 -Foundations of Computer Science II– Spring-2024

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Tutoring: https://computing.njit.edu/tutoring

Catalog Course Description

This course provides an introduction to automata theory, computability theory, and complexity theory. Theoretical models such as finite-state machines, push-down stack machines, and Turing machines are developed and related to issues in programming language theory. Also, the course covers undecidability and complexity classes P, NP, and NPC.

Detailed Description

This course presents some of the most fundamental results in theoretical computer science. These results attempt to answer, in a precise mathematical sense, the following two questions, which are of practical as well as philosophical interest:

1. Can a given problem be solved by computation?
2. How efficiently can a given problem be solved by computation?

We often focus on *problems* rather than on specific *algorithms* for solving problems. To answer both questions mathematically, we will need to formalize the notion of "computer" or "machine." The course outline breaks naturally into three parts:

1. Models of computation (Automata Theory)
   - Finite automata
   - Push-down automata
   - Turing machines
2. What can we compute? (Computability Theory)
3. How efficiently can we compute? (Complexity Theory)

Specifically, the topics covered will include regular languages (finite automata, regular expressions), nonregular languages, context-free languages (context-free grammars, pushdown automata), non-context-free languages, Turing machines and variants, Church-Turing Thesis, undecidability, reducibility, time complexity, and complexity classes P, NP, and NP-complete.

Text book

Michael Sipser, *Introduction to the Theory of Computation, Third Edition*. Course Technology, 2012, ISBN-10: 113318779X, ISBN-13: 978-1133187790.

Detailed Course Contents

Module I: Introduction to Languages and Automata: Formal Grammars and Chomsky Hierarchy, Regular Expression Deterministic and Nondeterministic Finite Automata, Regular Expression, Finite Automata with output, Properties of regular sets, pumping lemma for regular sets.

Module II: Context Free Grammars and Pushdown Automata: CFG: Formal Definition, Derivation and Syntax trees, Simplification Forms, Ambiguous Grammar, Properties: of CFL, Normal Forms (CNF and GNF), Pushdown Automata: Definitions, Relationship between PDA and context free language.

Module III: Turing Machine: The Turing Machine Model, Language acceptability of Turing Machine, Design of TM, Variations of TM, Universal TM, Church's Machine.

Module IV: Undecidability: Turing machine halting Problem, Post correspondence problems (PCP) and Modified Post correspondence problems, Undecidable problems.

Module V: Computability: Partial and Total Functions, Primitive Recursive functions, Recursive functions, Classes P, NP and NP complete.

Course Outcomes

The course outcomes of CS 341 are to

- Explain and prove the capabilities and limitations of different models of computation.
- Categorize and prove what problems can be solved by computation and which cannot.
- Categorize and prove what problems can be solved efficiently and those for which there is no known efficient solution.

The specific learning objectives are that after completing the course, students will be able to

- Classify and prove a particular language as regular, context-free, decidable, Turing-recognizable or non-Turing-recognizable.
- Design a finite automaton and regular expression for a regular language.
- Prove that a nonregular language is not regular.
- Design context-free grammar and pushdown automaton for a context-free language.
- Prove that a non-context-free language is not context-free.
- Design a Turing machine for a decidable language.
- Prove or disprove closure properties (under union, intersection, concatenation, complementation, Kleene star) of classes of languages.
- Prove that certain languages are undecidable or non-Turing-recognizable.
- Explain nondeterminism and its role in computation and complexity theory.
- Explain the significance of complexity classes P, NP, and NP-complete, and perform reduc- tions to prove NP-completeness of certain languages.

Prerequisites

Before taking CS 341, you must complete all of the following with grades of C or better:

1. A 100-series general undergraduate required course in CS
2. CS 241 (Foundations of Computer Science I)
3. CS 280 (Programming Language Concepts).

Assessment Strategy

The graded assessments in the course are two project(s) (programming assignment(s)), one midterm and a final exam. Your course grade will be based on the following weights:

- Assignments 20%
- Midterm exam 20%
- Project 30%
- Final exam 30%

Guidelines & Policies

Attendance: Attendance will be taken. Students are expected to attend the lectures in the section that they are registered in. Lectures are a sequence. If you skip one you will not be able to understand the lecture that follows, if you don't catch up with the one you missed. Catching up lectures is your responsibility and is done in your own time. Instructor has the right to modify the grading criteria to include attendance and class participation when necessary.

Email: Use of your NJIT email or Canvas inbox is strongly encouraged.

Grade Corrections: Check the grades in course work and report errors promptly. Please try and resolve any issue within one week of the grade notification.

Late submission: Homework assignments or projects or any other course related work assigned are expected to be submitted by the specified due date and time. Late submissions will not be accepted by default. In exceptional circumstances, a student may be allowed to submit a homework assignment after the due date. Late submissions will only be considered within a specific window of time, which is up to 5 days after the original due date. For each day an assignment is submitted late, a penalty of 10% of the total possible grade for that assignment will be deducted. This deduction will accumulate for each additional day of late submission. The maximum penalty for late submissions is 50% of the total possible grade for the assignment. After the 5-day late submission window has passed, no further submissions will be accepted. It is the responsibility of the student to manage their time effectively and submit assignments within the specified timeframe.

Exam and Proctoring Policy: All exams will be closed book and closed notes. Each midterm is held during regular class meeting times. The final exam will be given during the time slot assigned by the NJIT Registrar. See the NJIT Online Course Exam Proctoring page for information on proctoring tools and requirements.

Collaboration and External Resources for Assignments: Some homework problems will be challenging. You are advised to first try and solve all the problems **on your own**. For problems that persist you are welcome to talk to the course assistant or the instructor. You are also allowed to collaborate with your classmates and search for solutions online. But you should use such solutions only if you understand them completely (admitting that you don't understand something is way better than copying things you don't understand). Also make sure to give the appropriate credit and citation.

Requesting Accommodations: If you need an accommodation due to a disability please contact Scott Janz, Associate Director of the Office of Accessibility Resources and Services, Kupfrian Hall 201 to discuss your specific needs. A Letter of Accommodation Eligibility from the office authorizing student accommodation is required.

NJIT Services for Students, Including Technical Support: Please follow this link.

Canvas Accessibility Statement: Please follow this link.

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