

# CS 3350 Automata, Computability, and Formal Languages Spring 2022 Syllabus

**Class Time:** Tuesdays and Thursdays 12-1:20 pm

**Room:** LART 106

**General Prerequisites:** CS 2302 "Data Structures" and either Discrete Mathematics or Discrete Structures, both with grades C or higher.

**Alternative Prerequisites:** CS 2401 "Elementary Data Structures and Algorithms" and either Discrete Mathematics or Discrete Structures, both with grades B or higher.

**Instructor:** [Vladik Kreinovich](#), email [vladik@utep.edu](mailto:vladik@utep.edu), office CCSB 3.0404, office phone (915) 747-6951.

- The instructor's office hours are Tuesdays and Thursdays 1:30-3 pm, or by appointment.

Preferable way of contact is by email.

- If you want to contact the instructor during the scheduled office hours, there is no need to schedule an appointment.
- If you cannot contact the instructor during the instructor's scheduled office hours, please schedule an appointment in the following way:
  - use the instructor's appointments page [/vladik/appointments.html](#) to find the time when the instructor is not busy (i.e., when he has no other appointments), and
  - send him an email, to [vladik@utep.edu](mailto:vladik@utep.edu), indicating the day and time that you would like to meet.

He will then send a reply email, usually confirming that he is available at this time, and he will place the meeting with you on his schedule.

**Teaching Assistant (TA):** Laxman Bokati, email [lbokati@miners.utep.edu](mailto:lbokati@miners.utep.edu), office hours TBD. **Instructor of Another Section of Automata:** [Luc Longpre](#).

- Time Mondays and Wednesdays 12-1:20 pm.
- Dr. Longpre's email is [longpre@utep.edu](mailto:longpre@utep.edu).

**Course Objectives:** Theoretical computing models and the formal languages they characterize: Finite state machines, regular expressions, pushdown automata, context-free grammars, Turing machines and computability. Capabilities and limitations of each model, and applications including lexical analysis and parsing.

## Major Topics Covered in the Course

- Regular languages, finite automata (FA), non deterministic FA (NFA)
- Context-free languages, pushdown automata (PDA)
- Parsing, normal forms, ambiguity
- Pumping lemmas and closure properties
- Turing machines and other equivalent models
- Decidable languages, non-decidable languages, recognizable languages, Chomsky hierarchy

## Learning Outcomes

### Level 1: Knowledge and Comprehension

Level 1 outcomes are those in which the student has been exposed to the terms and concepts at a basic level and

can supply basic definitions. The material has been presented only at a superficial level.

Upon successful completion of this course, students will be able to:

- 1a. Describe implications of Church-Turing thesis.
- 1b. Describe problems for which an algorithm exists, and problems for which there are no algorithms (non-recursive, non-recursively enumerable languages) and describe the implications of such results.
- 1c. Describe and explain the diagonalization process as used in proofs about computability.
- 1d. Describe the difference between feasible and non-feasible algorithms, describe the limitations of the current formalization of feasibility as polynomial-time.
- 1e. Describe the main ideas behind the concepts of NP and NP-hardness, know examples of NP-hard problems.

### **Level 2: Application and Analysis**

Level 2 outcomes are those in which the student can apply the material in familiar situations, e.g., can work a problem of familiar structure with minor changes in the details.

Upon successful completion of this course, students will be able to:

- 2a. Convert a non-deterministic FA (respectively transition graph) into an equivalent deterministic FA.
- 2b. Convert a transition graph or NFA into an equivalent regular expression.
- 2c. Convert a regular expression into an equivalent FA.
- 2d. Construct a regular expression (respectively a context-free grammar) for a regular language (respectively context-free language).
- 2e. Convert a context-free grammar into an equivalent pushdown automaton.
- 2f. Construct a context-free grammar for a given context-free language.
- 2f. Design an algorithm for a machine model to simulate another model.
- 2h. Build simple Turing machines.
- 2i. Prove formally properties of languages or computational models.
- 2j. Apply a parsing algorithm.
- 2k. Build a parse tree or a derivation from a context-free grammar.
- 2l. Use the closure properties in arguments about languages.

### **Level 3: Synthesis and Evaluation**

Level 3 outcomes are those in which the student can apply the material in new situations. This is the highest level of mastery.

Upon successful completion of this course, students will be able to:

- 3a. Compare regular, context-free, recursive, and recursively enumerable languages.
- 3b. Compare FA, PDA, and Turing machines.

**Textbook:** *Introduction to the Theory of Computation*, by Michael Sipser (both 2nd and 3rd editions are OK). This book is available at the bookstore and through major online book retailers, and you are expected to acquire a copy for your use in this course. Photocopied textbooks are illegal and their use will not be tolerated.

**Assignments:** Reading and homework assignments will be announced on the class website. You should expect to spend at least 10 hours/week outside of class on reading and homework.

**Exams:** There will be three tests: on February 17, March 24, and April 28, and the final exam on May 10, 1-3:45 pm.

Similar to homeworks, I will post solution, send you the grades, and answer questions if something is not clear.

As usual, if you are unable to attend the test, let me know, I will organize a different version of the text at a time convenient for you.

**Grading:** Each topic means home assignments (mainly on the sheets of paper, but some on the real computer). Maximum number of points:

- attendance: 5
- first test: 15
- second test: 15
- third test: 15
- home assignments and quizzes: 20
- final exam: 30

The nominal percentage-score-to-letter-grade conversion is as follows:

- 90% or higher is an A
- 80-89% is a B
- 70-79% is a C
- 60-69% is a D
- below 60% is an F

We reserve the right to adjust these criteria downward, e.g., so that 88% or higher represents an A, based on overall class performance. The criteria will not be adjusted upward, however.

**Homework Assignments:** Each topic means home assignments. Homeworks will be usually assigned on Tuesday and be due on Thursday, by the start of the Thursday class. To submit a homework, send it to the Teaching Assistant (TA) by email. If it is not electronic, scan it and send him/her the scanned version. If you have a legitimate reason to be late, let me and the TA know, you can then submit it until the following Tuesday. If you were simply late, you can still submit until next Tuesday, but then the TA will take off points for submitting late.

The TA will take off points for submitting late. He/she will send you the grades. On Tuesday the next week, I will post correct solutions, and both I and the TA will be glad to answer questions if needed.

Since I will be posting correct solutions to homeworks, it does not make any sense to accept very late assignments: once an assignment is posted, it make no sense for you to copy it in your own handwriting, this does not indicate any understanding. So, please try to submit your assignments on time.

Things happen. If there is an emergency situation and you cannot submit it on time, let me know, you will then not be penalized -- and I will come up with a similar but different assignment that you can submit directly to me (not to the TA) when you become available again.

Homework must be done individually. While you may discuss the problem in general terms with other people, your answers and your code should be written and tested by you alone. If you need help, consult the instructor or

the TA.

**Quizzes:** The purpose of a quiz is to ensure that you have read the weekly reading assignment and to verify that you have mastered the major concepts of recent lectures. Quizzes typically will be about 5-10 minutes in length and will cover the material assigned to be read for the upcoming lecture plus selected concepts from previous lectures. There will be no make-up on missed quizzes.

**Special Accommodations:** If you have a disability and need classroom accommodations, please contact the Center for Accommodations and Support Services (CASS) by email to [cass@utep.edu](mailto:cass@utep.edu). For additional information, please visit the CASS website at <http://www.sa.utep.edu/cass>. CASS's staff are the only individuals who can validate and if need be, authorize accommodations for students.

**Scholastic Dishonesty:** Any student who commits an act of scholastic dishonesty is subject to discipline. Scholastic dishonesty includes, but not limited to cheating, plagiarism, collusion, submission for credit of any work or materials that are attributable to another person.

*Cheating is:*

- copying from the test paper of another student;
- communicating with another student during a test to be taken individually;
- giving or seeking aid from another student during a test to be taken individually;
- possession and/or use of unauthorized materials during tests (i.e. crib notes, class notes, books, etc.);
- substituting for another person to take a test;
- falsifying research data, reports, academic work offered for credit.

*Plagiarism is:*

- using someone's work in your assignments without the proper citations;
- submitting the same paper or assignment from a different course, without direct permission of instructors.

To avoid plagiarism see: [https://www.utep.edu/student-affairs/osccr/\\_Files/docs/Avoiding-Plagiarism.pdf](https://www.utep.edu/student-affairs/osccr/_Files/docs/Avoiding-Plagiarism.pdf)

*Collusion* is unauthorized collaboration with another person in preparing academic assignments.

Instructors are required to -- and will -- report academic dishonesty and any other violation of the Standards of Conduct to the Dean of Students.

NOTE: When in doubt on any of the above, please contact your instructor to check if you are following authorized procedure.

**Daily Schedule:** (tentative and subject to change)

*January 18:* topics to cover:

- motivations for the class: basis for compiler design; need to detect when a task is not algorithmically solvable; see [lecture](#);
- notion of a finite automaton; see [lecture](#).

*January 20:* topics to cover:

- simple examples of finite automata -- for recognizing integers and for recognizing real numbers; see [lecture](#);
- formal notations for describing a finite automaton; see [lecture](#);
- algorithms for designing a finite automata that recognize union and intersection of regular languages; see [lecture](#).

*January 25:* topics to cover:

- notion of a non-deterministic automaton (NFA);
- how to transform NFAs recognizing two languages into an NFA for their union;
- notion of concatenation of two languages;
- how to transform NFAs recognizing two languages into an NFA for their concatenation;
- the notion of a Kleene star;
- how to transform a NFA recognizing a language into a NFA for recognizing its Kleene star;
- notion of a regular expression;
- how to transform a NFA into a deterministic one;

see [lecture](#).

*January 27:* topics to cover:

- how to transform a finite automaton into a corresponding regular expression; see [lecture](#);
- how to simulate finite automata; see [lecture](#).

*February 1:* topics to cover:

- Pigeonhole Principle; Pumping Lemma; see [lecture](#);
- proof that some languages are not regular; examples of non-regular languages; see [lecture](#).

*February 3:* topics to cover:

- notion of a pushdown automaton; examples of pushdown automata; see [lecture](#);
- notion of a context-free grammar; examples of context-free grammars related to programming; examples of context-free grammars that generate non-regular languages; see [lecture](#).

*February 8:* topics to cover:

- how to transform a finite automaton into a context-free grammar; see [lecture](#);
- how to transform a context-free grammar into a (non-deterministic) pushdown automaton; see [lecture](#).

*February 10:* topics to cover:

- ambiguous vs. unambiguous grammars; see [lecture](#);
- Chomsky normal form; see [lecture](#).

*February 15:* overview for Test 1.

*February 17:* Test 1.

*February 22:* overview of Test 1 results.

*February 24:* topics to cover:

- Chomsky normal form (cont-d); see [lecture](#);
- transforming a pushdown automaton into a context-free grammar; see [lecture](#).

*March 1:* topics to cover:

- transforming a pushdown automaton into a context-free grammar (cont-d); see [lecture](#);
- how compilers actually work: priority technique; see first part of the [lecture](#).

*March 3:* topic to cover:

- priority techniques beyond simple arithmetic expression; see second part of the [lecture](#).

*March 8:* topic to cover:

- compiling LL(k) languages; see [lecture](#).

*March 10:* topics to cover:

- Pumping Lemma for context-free grammars;
- proof that some languages are not context-free;

see [lecture](#).

*March 22:* preview for Test 2

*March 24:* Test 2

*March 29:* review of Test 2 results

*March 31:* topics to cover:

- main ideas behind Turing machines;
- unary code;
- Turing machines for processing numbers in unary code;
- lowest-bit first vs. highest-bit first computer representation of numbers;
- Turing machines for simple operations with binary numbers;
- how to transform a finite automaton into a Turing machine;

see [lecture](#).

*April 5:* topics to cover:

- how to simulate a Turing machine; see [lecture](#);
- how to represent a Turing machine as a finite automaton with two stacks; see [paper](#).

*April 7:* topics to cover:

- feasible vs. non-feasible algorithms;
- example showing that the current definition of feasibility is not always adequate;

see Section 2.1.1 of a [paper](#) and [comments](#)

*April 12:* topics to cover:

- a general notion of a problem -- examples, resulting definition of the class NP;
- class P;
- P = NP problem;
- notion of reduction; examples of reduction;
- notion of NP-hardness and NP-completeness;
- examples of NP-hard problems;

see [lecture](#) and Sections 2.2 and 2.3 of the [paper](#).

*April 14:* topics to cover:

- proof by contradiction: general idea;

- proof that square root of 2 is not a rational number;

see [lecture](#).

*April 19:* topics to cover:

- definition of a halting problem;
- proof that it is not possible to check whether a given program halts on given data;

see [lecture](#).

*April 21:* topics to cover:

- Church-Turing thesis: what is it, is it a mathematical statement, is it a statement about the physical world; see [lecture](#);
- the notion of a recursive (decidable) language; the notion of a recursively enumerable (Turing-recognizable) language; see [lecture](#).

*April 26:* preview for Test 3

*April 28:* Test 3.

*May 3:* topics to cover:

- overview of Test 3 results;
- Church-Turing thesis: what is it, is it a mathematical statement, is it a statement about the physical world; see [lecture](#);
- the notion of a recursive (decidable) language; the notion of a recursively enumerable (Turing-recognizable) language; see [lecture](#).

*May 5:* preview for final exam.