CS 6041
Theory of Computation

Overview

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https://kevinsuo.github.io/

Self Introduction

- Kun Suo, Ph.D.
  - Homepage, https://kevinsuo.github.io/

- Research interests:
  - Cloud computing and virtualization;
  - Operating systems, containers and kubernetes;
  - Software defined network (SDN) and network function virtualization (NFV)
  - Big data systems and machine learning systems

- Projects you may be interested in:
  - Several projects in Cloud & Data & Edge
  - https://kevinsuo.github.io/code-lab.html

Now it's your turn

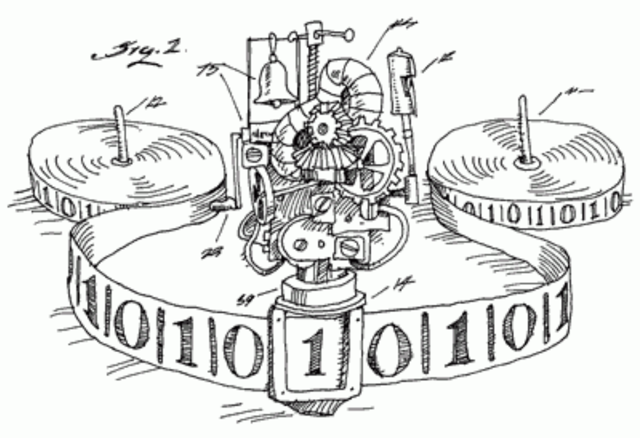
- Name, program/year, where from
- Your interests in Computer Science
- What do you expect in the Theory of Computation?

https://www2.eecs.berkeley.edu/Research/Areas/CS/

If you are in the online course, introduce yourself in D2L, Discussions → Self-Introduction

What does Theory of Computation include?

- A study of topics from theoretical computer science that includes
  - Automata and languages
  - Computability theory
  - Complexity theory



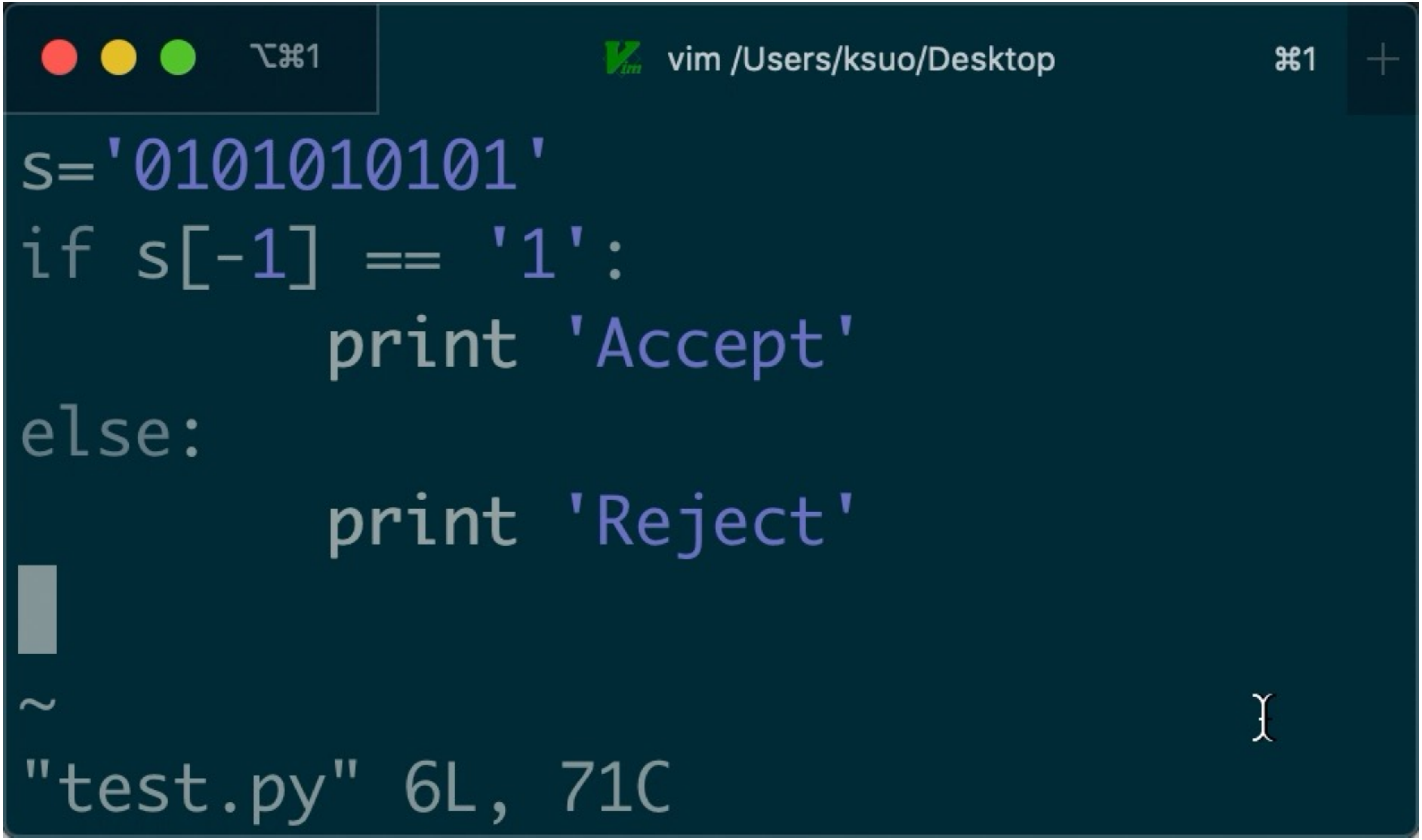
- How efficiently (how fast, how much space, etc.) problems can be solved on a model of computation, using an algorithm

What does Theory of Computation include?

- Example 1: L = {s | Binary strings end in 1s}.
  - Is it computable?
  - How can human beings solve it?
  - Can you build a machine to solve it?

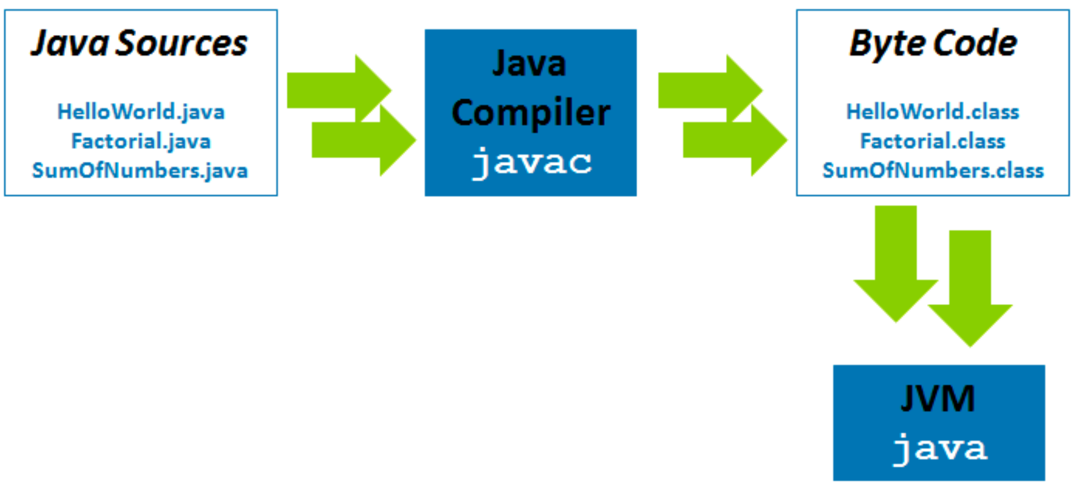
0101010100011	Accept
010100010	Reject

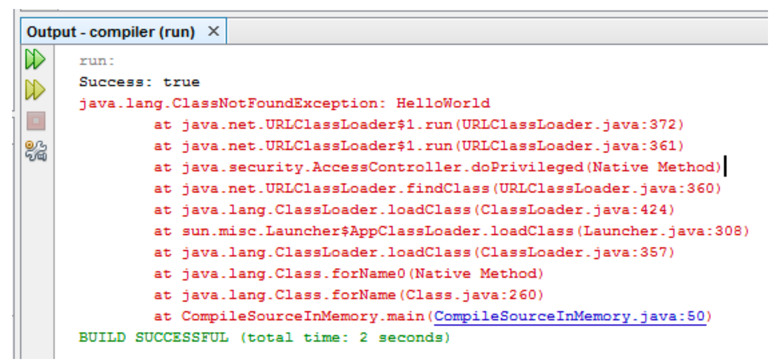
What does Theory of Computation include?



What does Theory of Computation include?

- Example 2: Accepts all valid Java code.
  - Is it computable?
  - Can you build a machine to solve it?
  - How can human beings solve it?





What does Theory of Computation include?

- Example 3 (halting problem): for input w, determine whether w will end in finite time or infinite loop.
  - Is it computable?
  - Can you build a machine to solve it?
  - How can human beings solve it?

There is no program that solves the halting problem.

This proof was found by Alan Turing in 1936.

https://scholar.google.com/scholar?hl=en&as_sdt=0%2C11&q=ON+COMPUTABLE+NUMBERS%2C+WITH+AN+APPLICATION+TO+THE+ENTSCHEIDUNGSPROBLEM&btnG=

What does Theory of Computation include?

- Example 1: Binary strings end in 0s.
- Example 2: Accepts all valid Java code.
- Example 3 (halting problem): for input w, determine whether w will end in finite time or infinite loop.

Easy vs Hard vs Not computable

Simple machine vs Complicated machine (with knowledge)

Fast vs Slow vs Not answer (proof)

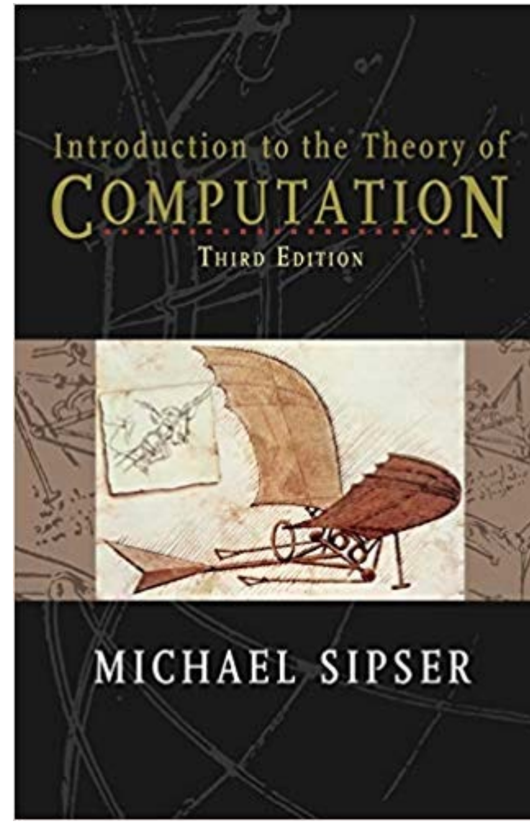
1KB vs 500MB vs …

Course Information

- Instructor: Dr. Kun Suo
- Office: J-318
- Email: ksuo@kennesaw.edu,
  - Only reply to e-mails that are sent from KSU student email accounts and title the course number [CS6041]
- Class Hours: online D2L
- Office Hours:
  - M/W, 4:00pm-5:00pm
  - By appointment
- Course Materials
  - Homework assignments, lecture slides, and other materials will be posted in the webpage (https://kevinsuo.github.io/teaching.html) and D2L.
  - All lectures will be recorded.

Reference Book

- Professor Michael Sipser (MIT)
- Introduction to the Theory of Computation
- 3rd edition, Cengage Learning ISBN 13-978-1-133-18779-0
- Buy/Rent/eBook/Library



Grading Policy

- Grading percentage
  - ~~In-class discussion and attendance: 5%~~
  - Homework (6x): 40% (please submit pdf file on D2L)
    - ~~One course presentation: https://docs.google.com/spreadsheets/d/1kGszd_RWYSKGaXkznMFz3mBWH17bPJvnzU8haclL_Co/edit?usp=sharing~~
  - 1st Midterm: 20%
  - 2rd Midterm: 20%
  - 3rd Final exam: 20%

*Late submission is **not accepted**.*

Course Policy

- Grading scale

Percentage	Grade
90 - 100	A
80 - 89	B
70 - 79	C
60 - 69	D
Below 60	F

Academic Integrity

- Academic dishonesty
  - Cheating
  - Plagiarism
  - Collusion
  - The submission for credit of any work or materials that are attributable in whole or in part to another person
  - Taking an examination for another person
  - Any act designed to give unfair advantage to a student or the attempt to commit

https://scai.kennesaw.edu/KSU_Codes_of_Conduct_2019-2020.pdf

Receiving, attempting to receive, knowingly giving or attempting to give unauthorized assistance…

How to succeed this class

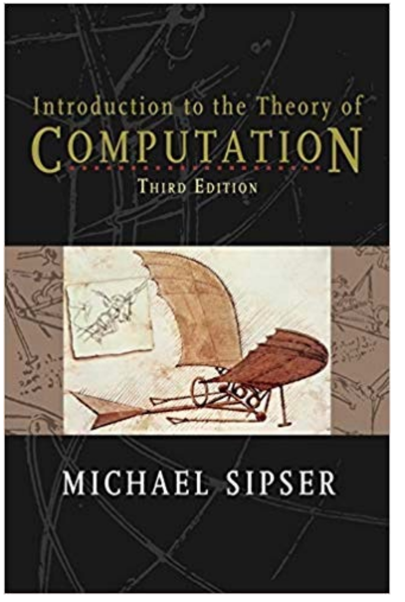
- THINK hard, not WORK hard
- Scientific Thinking
- Passion to learn something NEW
- ASK ME (office hours) / Friends / Classmates questions
- Begin homework assignments EARLY

Where to go for help ?

- Ask questions in class
- Ask questions outside class
  - Classmates and friends
- Attend office hours
  - Dr. Kun Suo: M/W 4:00PM – 5:00PM, J-318 or make an appointment
- Search on the web
  - Stand on the shoulder of giants

Course Content Overview

- 0. Introduction
- 1. Regular language
- 2. Context-free language
- 3. Turing machine
- 4. Decidability
- 5. Reducibility
- 6. Advanced Topics in Computability Theory
- 7. Time complexity
- 8. Space complexity
- 9. Intractability
- 10. Advanced topics in complexity theory



Course Content Overview

- Chapter 0 Introduction
- Chapter 1 Regular Languages
- Chapter 2 Context-Free Languages
- Chapter 3 The Church-Turing Thesis
- Chapter 4 Decidability
- Chapter 5 Reducibility
- Chapter 7 Time Complexity

Course Content Overview

- Chapter 0 Introduction
- Chapter 1 Regular Languages
- Chapter 2 Context-Free Languages
- Chapter 3 The Church-Turing Thesis
- Chapter 4 Decidability
- Chapter 5 Reducibility
- Chapter 7 Time Complexity

Exam 1

Exam 2

Exam 3

Course Content Overview

Week/Date	Topic	Chapters	Assignment
1	Introduction and overview	0	HW1
2	Deterministic finite automata	1.1	
2	Nondeterministic finite automata	1.2	HW2
3	Regular expression and Regular language	1.3	
3	Non-regular language	1.4	HW3
4	Exam 1		
4	Context free language	2.1	HW4
5	Pushdown Automata	2.2	
5	Non-Context free language	2.3	
6	Exam 2		
6	Turing machine	3	HW5
7	Decidability	4	
7	Reducibility	5	HW 6
8	Complexity and NP-completeness	7	
8	Conclusion		
9	Exam 3		

Language is the foundation of computation

```java
package rentalStore;
import java.util.Enumeration;
import java.util.Vector;

class Customer {
    private String _name;
    private Vector<Rental> _rentals = new Vector<Rental>();

    public Customer(String name) {
        _name = name;
    }
    public String getMovie(Movie movie) {
        Rental rental = new Rental(new Movie("", Movie.NEW_RELEASE), 10);
        Movie m = rental._movie;
        return movie.getTitle();
    }
    public void addRental(Rental arg) {
        _rentals.addElement(arg);
    }
    public String getName() {
        return _name;
    }
```

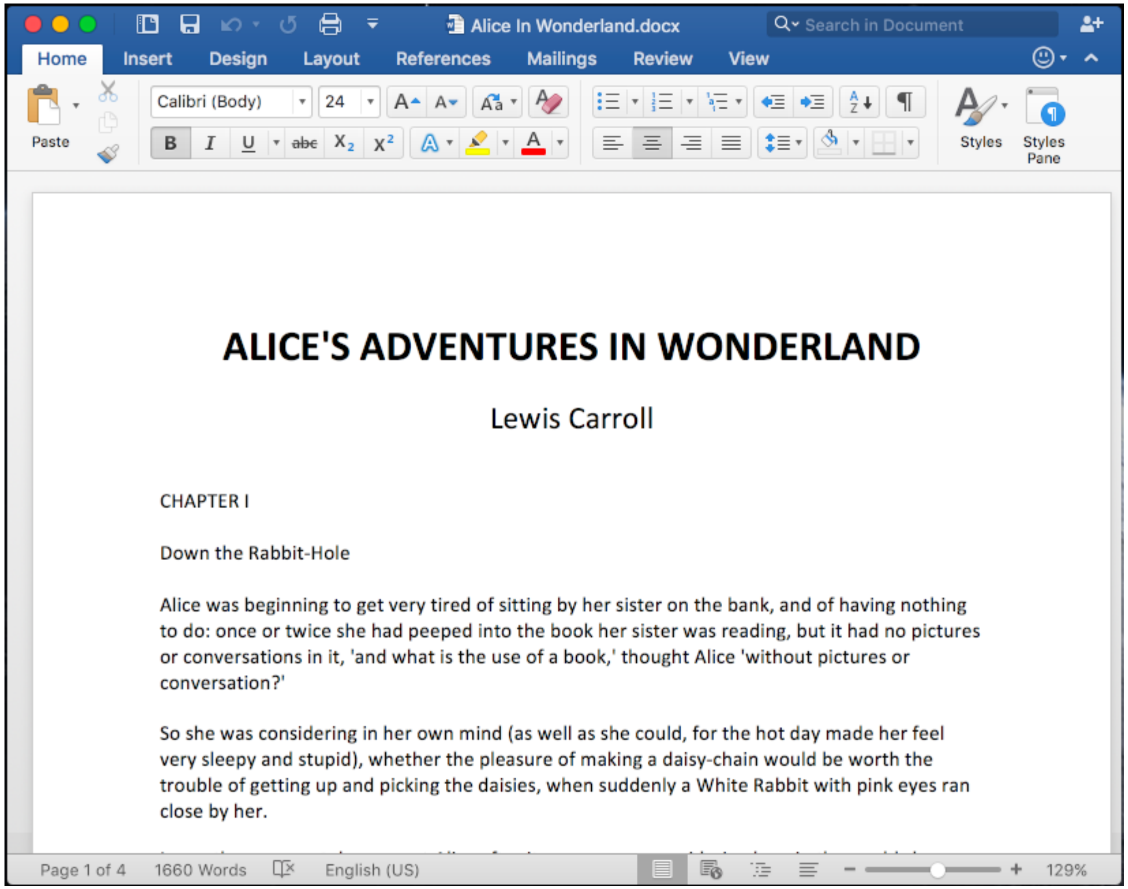
Java source code

Read by people

Binary code

Read by machines

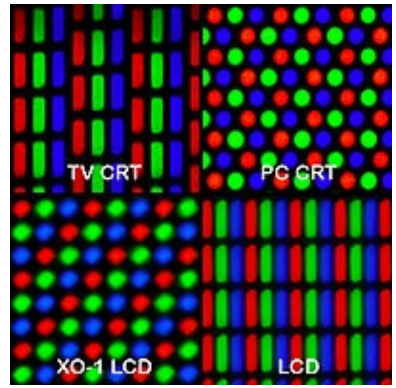
Language is the foundation of computation

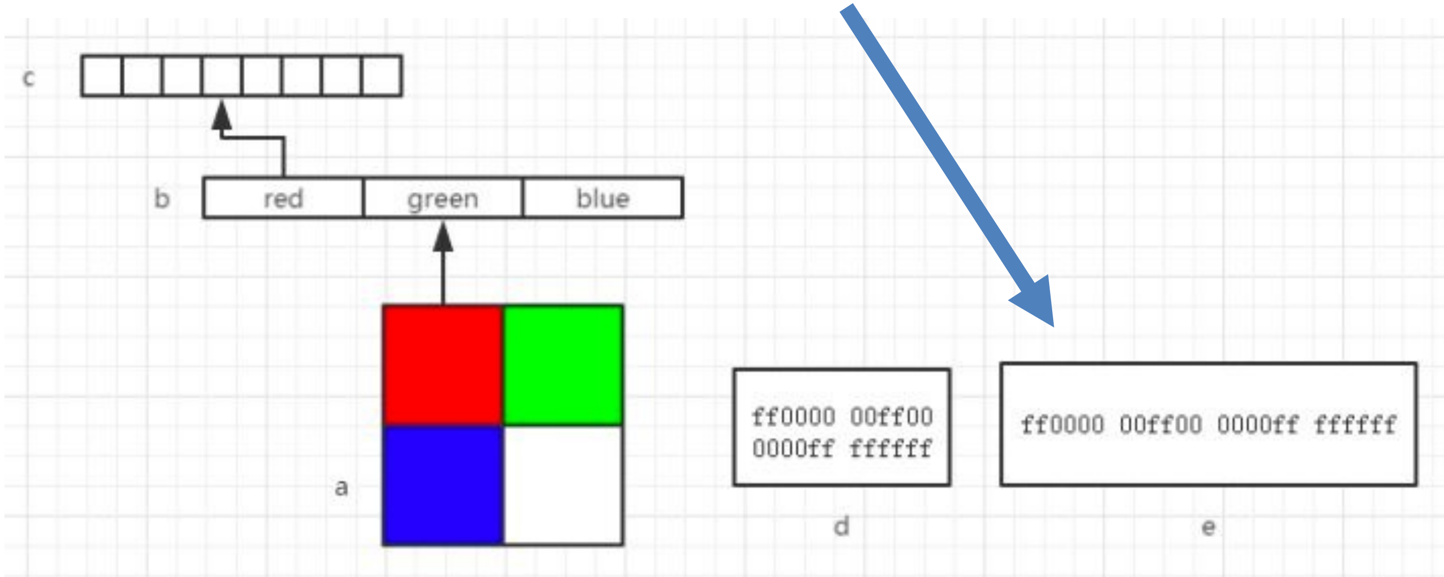


A word document is a language

Language is the foundation of computation

A figure is a language





Language universe in a big picture

- Are the languages all the same?

Language universe in a big picture

- Are the languages all the same?

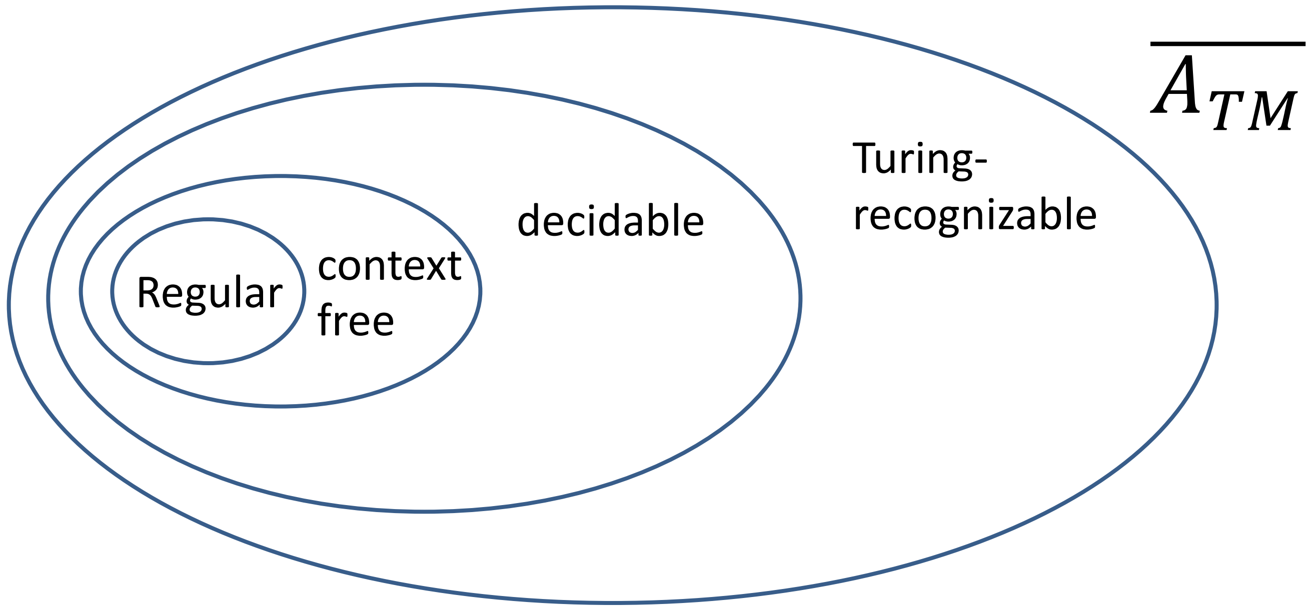
Satellite << Planet << Star << …

Earth

Solar system

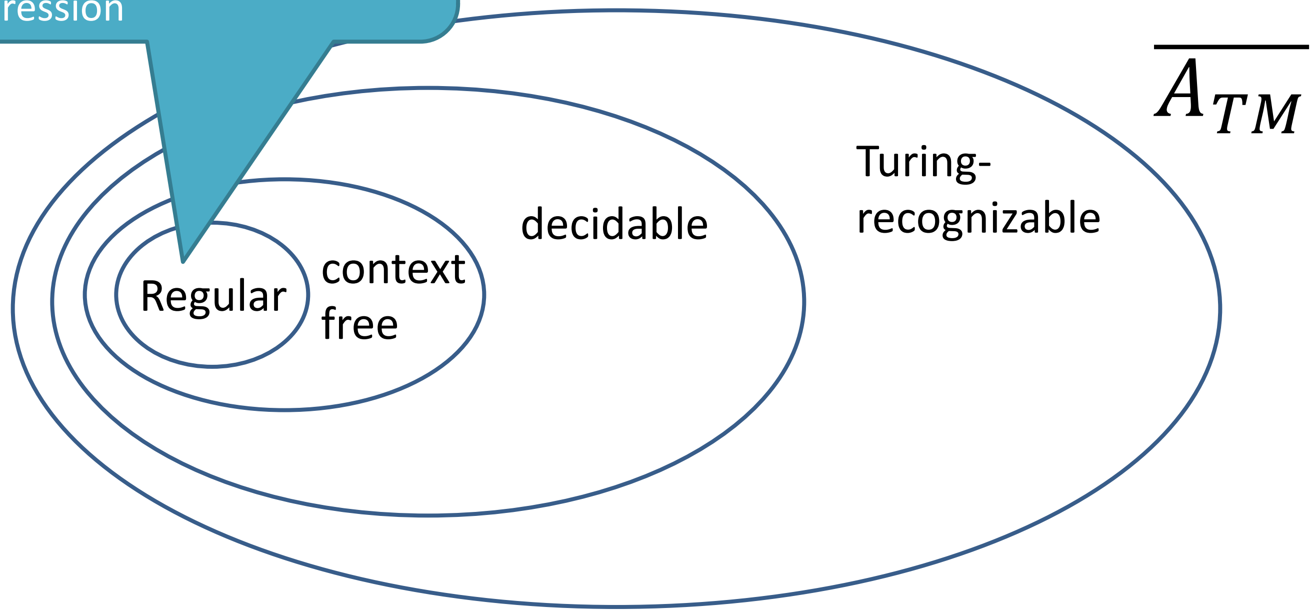
Galaxy

Language universe in a big picture

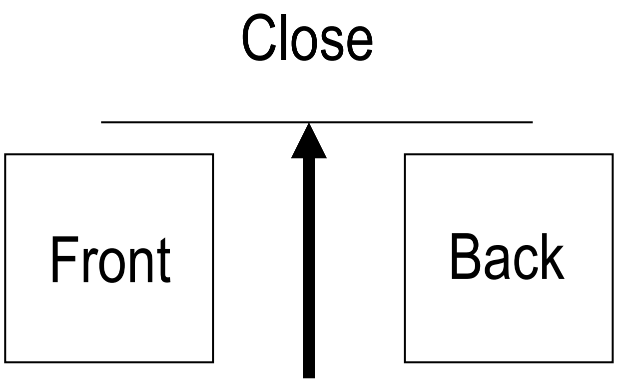


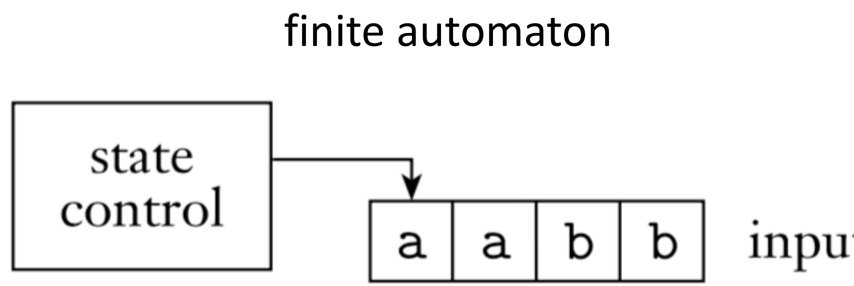
Language universe in a big picture

Regular language <==>
DFA: deterministic finite automata
NFA: non-deterministic finite automata
RE: regular expression



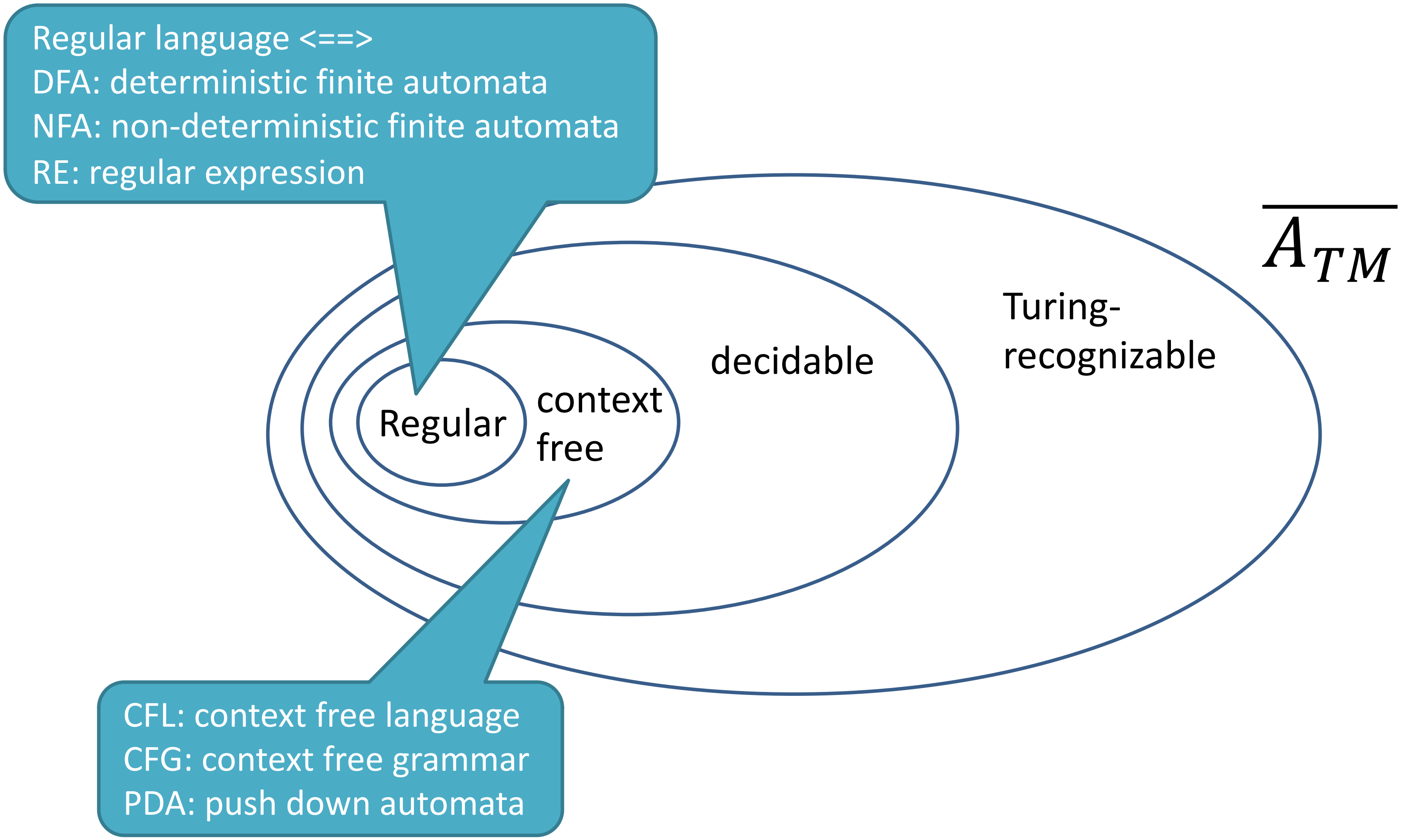
Language universe in a big picture





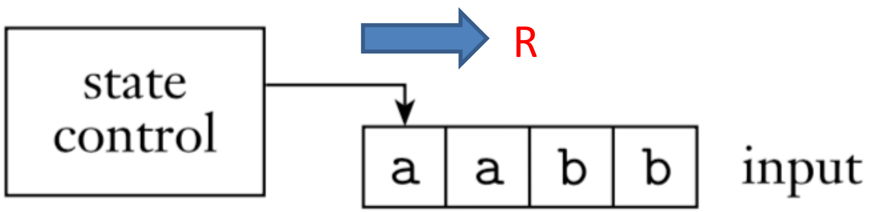
DFA example:
Automatic Door

Language universe in a big picture



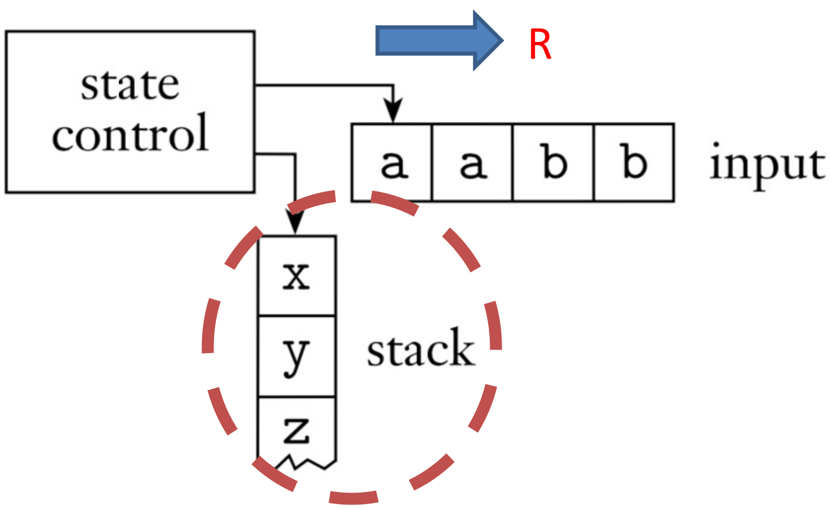
Language universe in a big picture

finite automaton



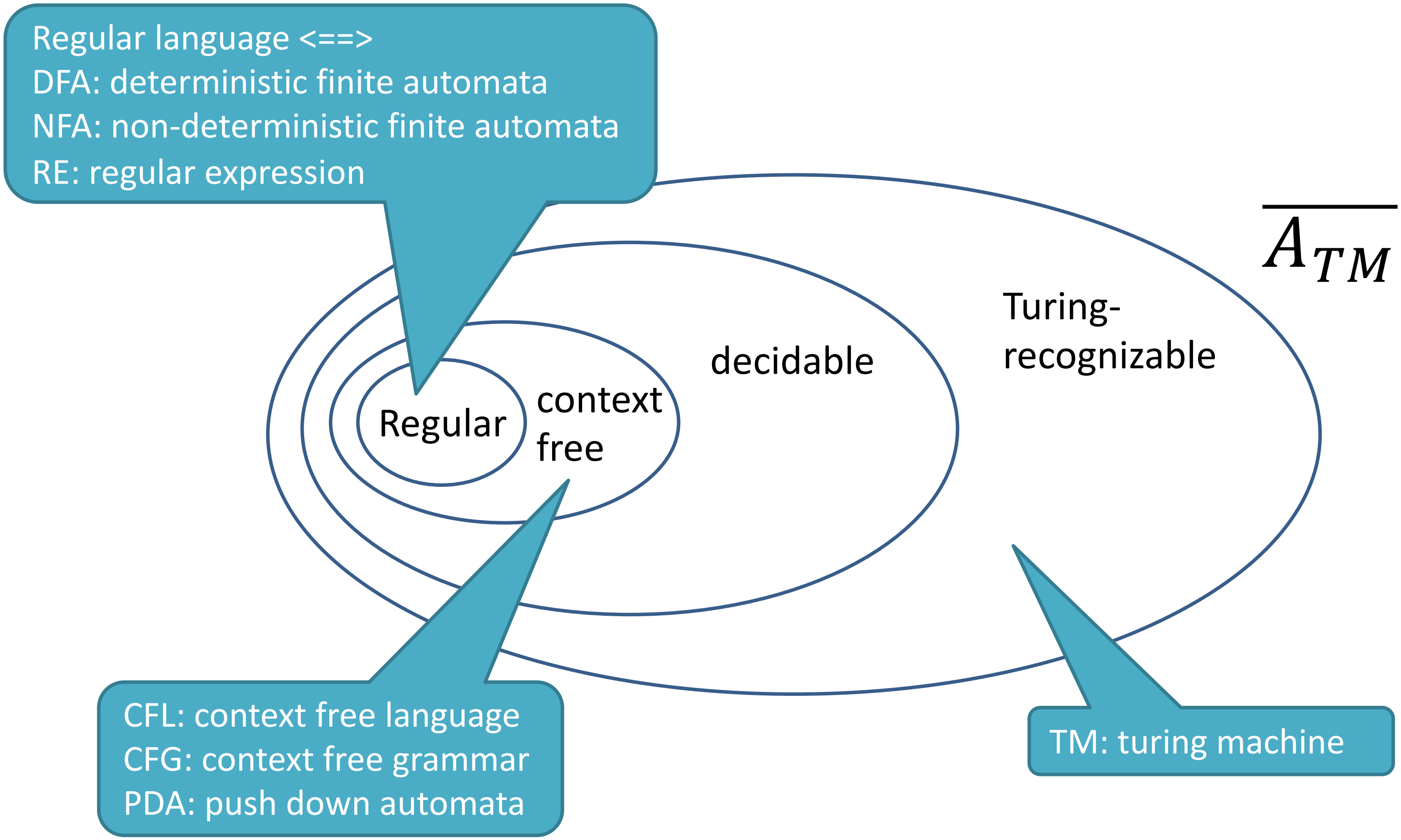
memory size = 1

pushdown automaton



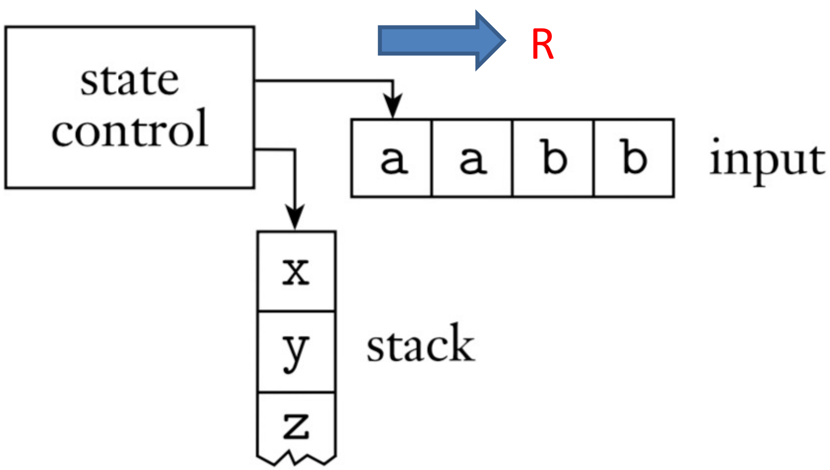
Not only current input
But also previous inputs

Language universe in a big picture

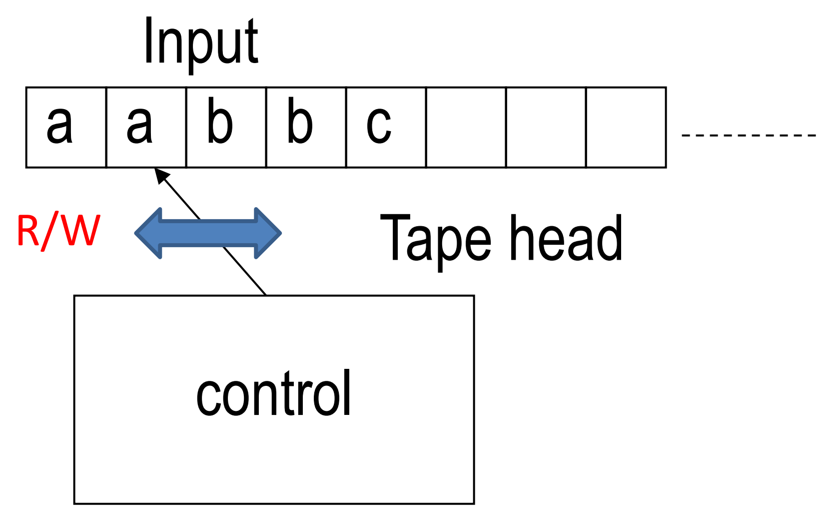


Language universe in a big picture

pushdown automaton



Turing machine

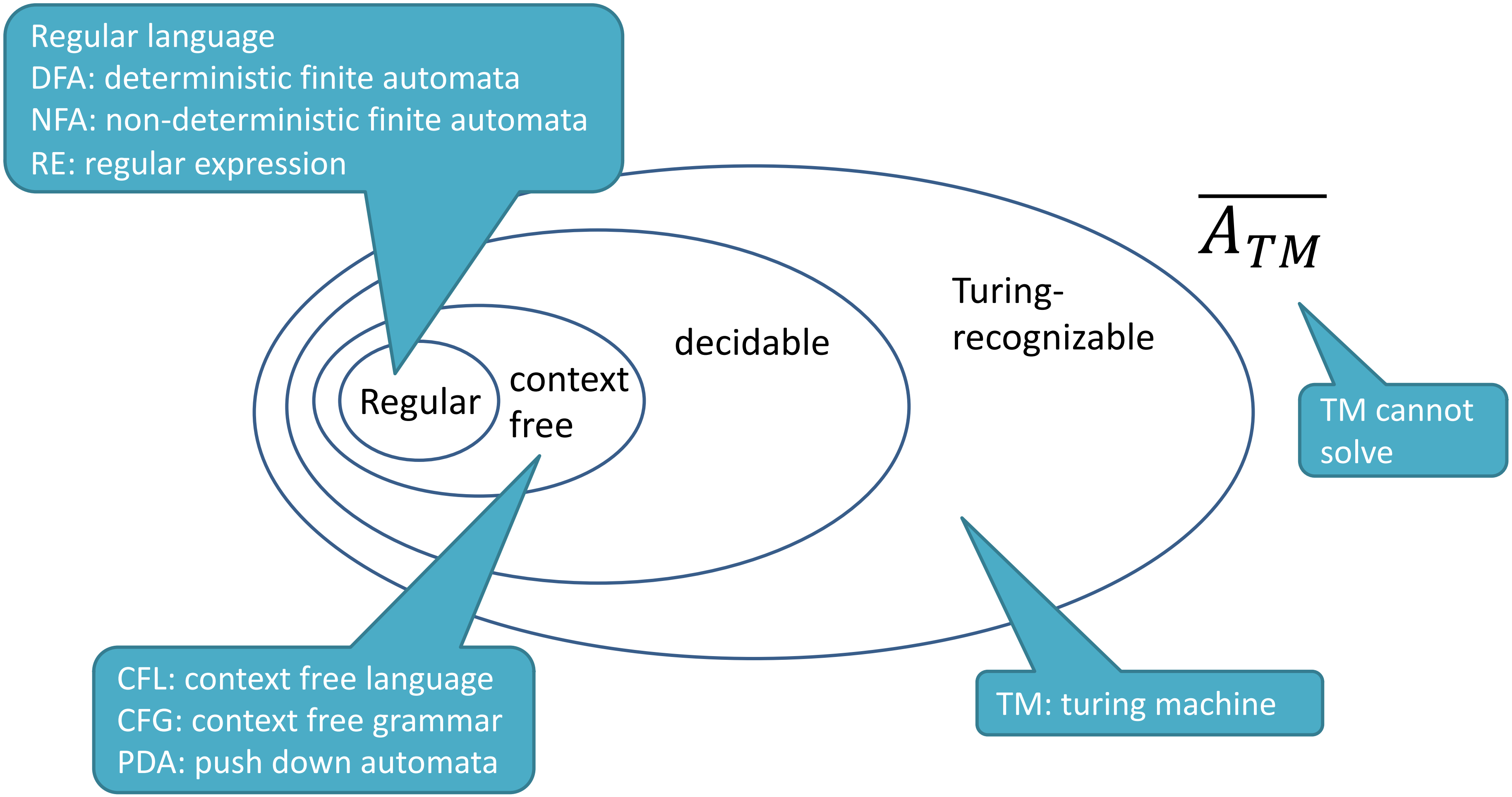


Turing machines are equivalent to modern electronic computers at a certain theoretical level, but differ in details.

Language universe in a big picture

https://www.youtube.com/watch?v=E3keLeMwfHY

Language universe in a big picture



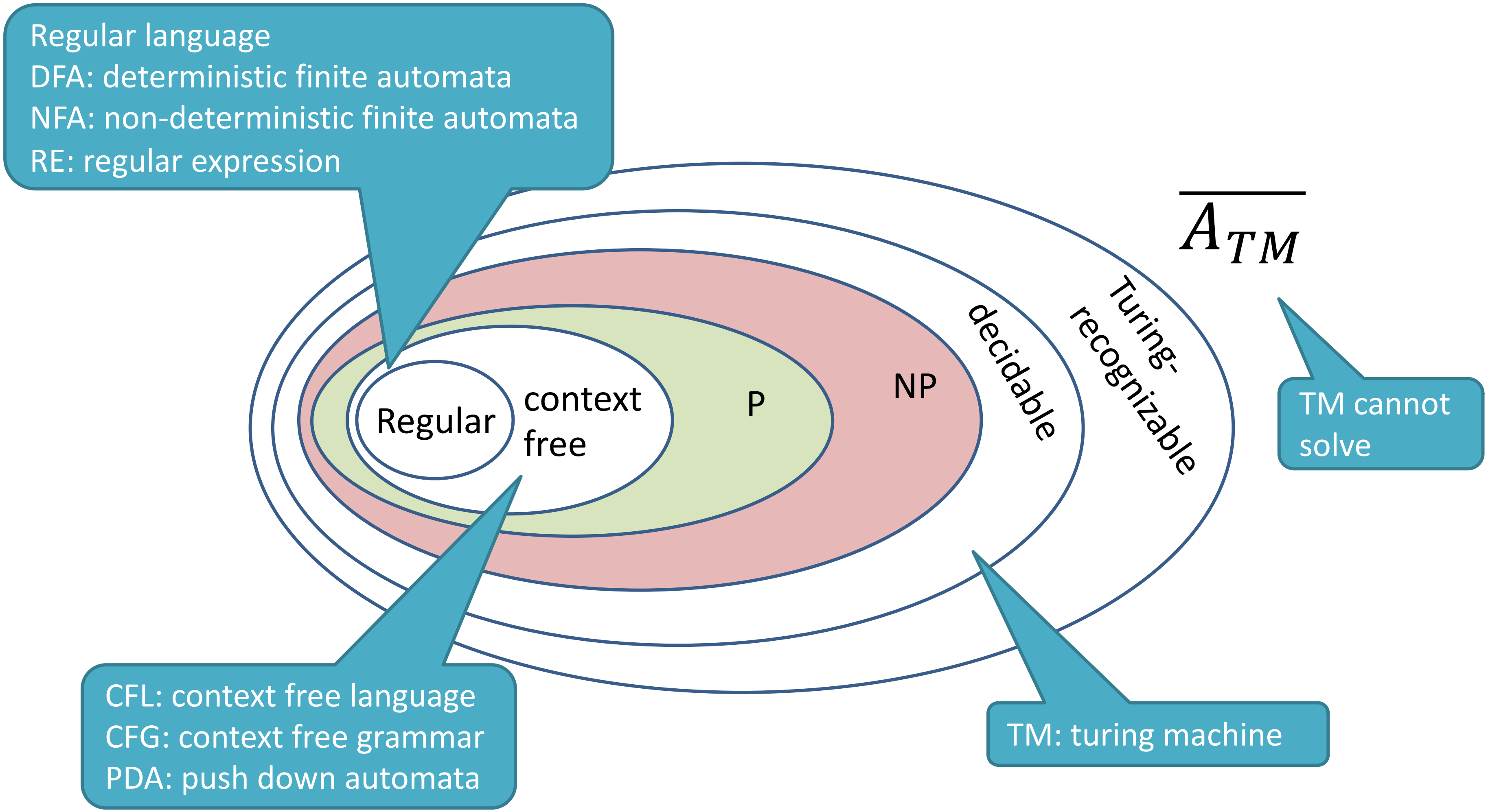
Language universe in a big picture

- P problem:
  - The general class of questions for which some algorithm can provide an answer in polynomial time
  - Give the answer!
- NP problem:
  - The class of questions for which an answer can be verified in polynomial time
  - Test the answer!

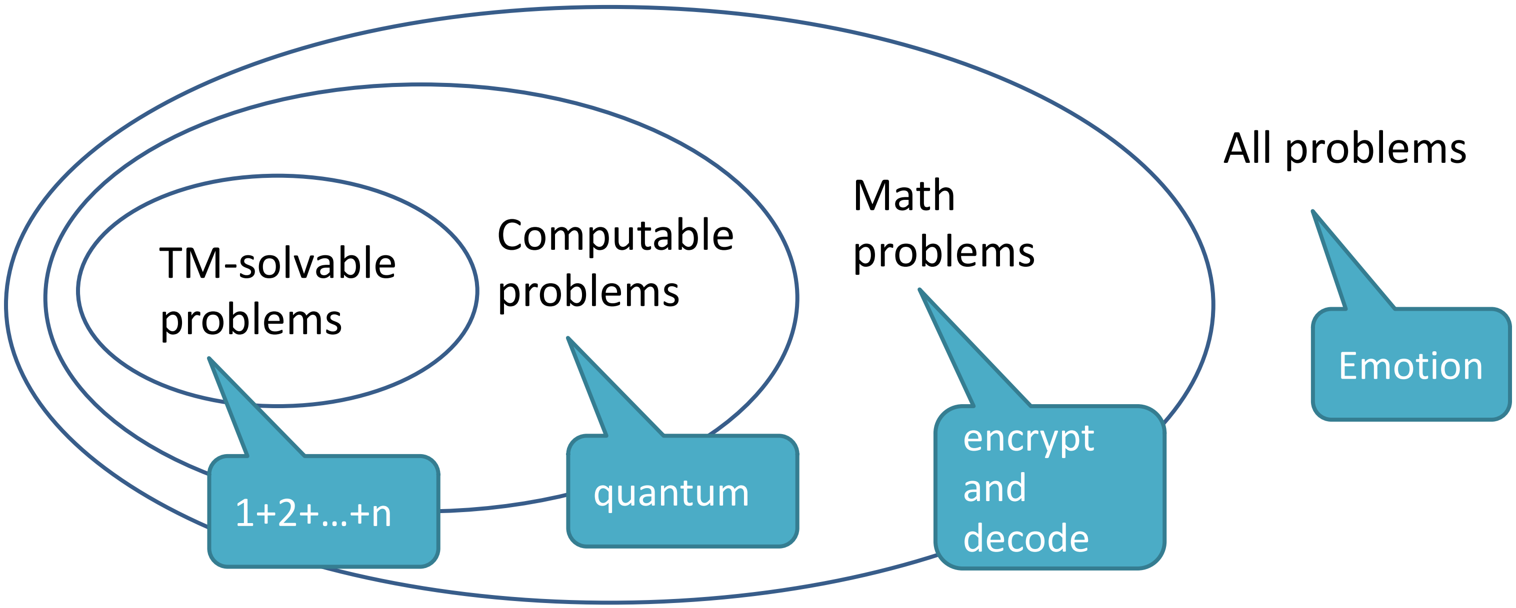
Language universe in a big picture

- P problem:
  - Give the answer!
  - E.g., Sorting for n numbers, no longer than $O(n^2)$
- NP problem:
  - Test the answer!
  - E.g., whether a given set has a subset that the sum of all its element is 0.
  - s={-1,3,2,-5,6}. subset={3,2,-5}, test in O(n) time

Language universe in a big picture



Problems



- Only a small proportion of problems can be solved by Turing machines in real life

Conclusion

- Introduction of course
  - Information, book, grading, …
- Course content overview
  - Calendar, content, schedule, …
- Language universe in a big picture
  - Regular language
  - CFL
  - Turing machine
  - P vs. NP