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Turing Machines

(Part 1)

Lecture 15

Day 15/31

CS 154

Formal Languages and Computability

Spring 2019

Agenda of Day 15

- Summary of Lecture 14
- Quiz 5
- A Few Slides from the Past (Added the slides to the Lecture 14)
- Lecture 15: Teaching …
  - Turing Machines (Part 1)
- Team Formation

Summary of Lecture 14: We learned ...

NPDAs

- How can we create nondeterministic PDA?
  1. λ-transition
  2. Multifunction δ
- We can create a λ-transition by putting λ in the condition positions.
- For NPDAs, a λ-transition is labeled as:

  λ, λ; w
- But w is a string and can be λ.
- So, "λ, λ; λ" is a λ-transition and is used extensively.

- We took some examples for multifunction transitions.
- As usual, machines start parallel processing when they have multiple choices.
- The procedure of initiating a new process is exactly the same as NFAs.
- PDAs configuration ...
  1. Current state
  2. Input string + Position of the read-head
  3. The stack and its content

Any question?

Summary of Lecture 14: We learned ...

NPDAs Formal Definition

- Formally, we defined NPDAs as:

$$M = (Q, \Sigma, \Gamma, \delta, q_0, Z, F)$$

- We added Γ and Z to NFAs'.
- The other change is δ ...

$$\delta: Q \times (\Sigma \cup \{\lambda\}) \times (\Gamma \cup \{\lambda\}) \rightarrow 2^{Q \times \Gamma^*}$$

- Sub-rule example:

$$\delta(q_1, a, x) = \{(q_2, yx), (q_3, \lambda)\}$$

Any question?

NAME	Alan M. Turing		
SUBJECT	CS 154	TEST NO.	5
DATE	03/14/2019	PERIOD	1 / 2 / 3

TEST RECORD	
PART 1	123
PART 2	
TOTAL	

Your list # goes here!

Quiz 5

Use Scantron

A Few Slides From the Past

Added Them to the Lecture 14

Turing Machines

Template for Constructing a New Class of Automata

Repeated

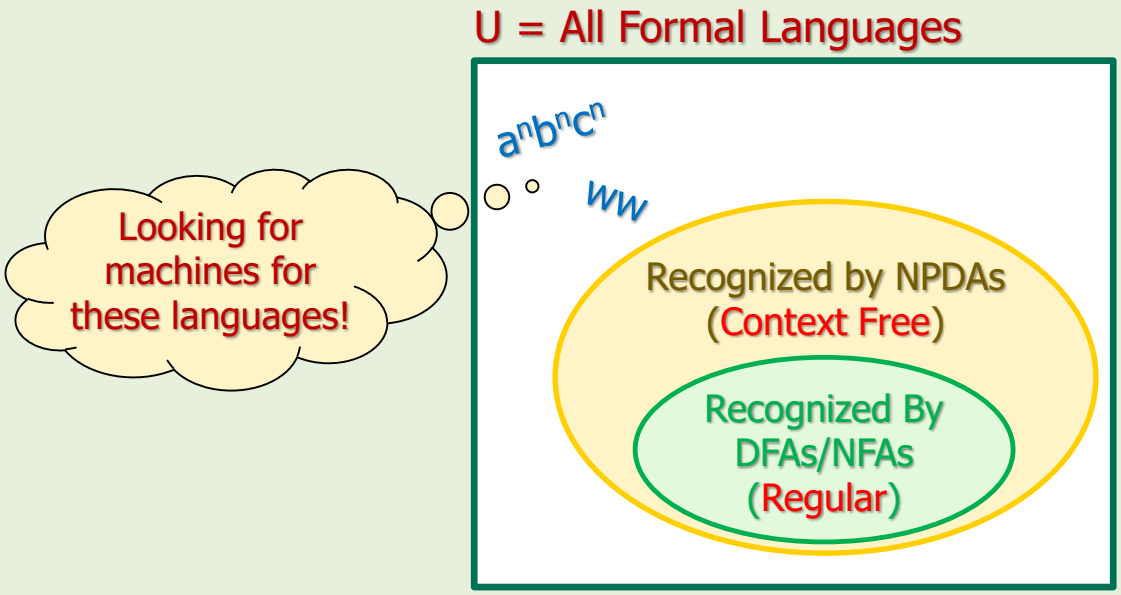
- To construct a new class of automata, we need to respond the following questions:

1. Why do we need a new class of machines? (Justification)
2. Name of the new class
3. Building blocks of the new class
4. How they work
   - 4.1. What is the starting configuration?
   - 4.2. What would happen during a timeframe?
   - 4.3. When would the machines halts?
   - 4.4. How would a string be Accepted/Rejected?
5. The automata in action
6. Formal definition
7. Their power: this class versus previous class
8. What would be the next possible class?

1. Why We Need a New Class

- This was our last conclusion:

  There are some languages for which we cannot construct NPDAs!



1. Why We Need a New Class

What Was Missing in NPDAs?

- We had stack (a writable memory) for counting but ...
  1. ... stack is not so flexible in storing and retrieving data.
  2. ... we lose some data when we access the older data.

- We need more control on the memory.

- So, we are going to replace the stack with a more flexible memory.
- What is more flexible than stack?
- RAM (random access memory)!

2. Name of the New Class

- This machine was proposed by Alan M. Turing in 1936.
- That's why we call it:

Turing machine (TM)

- Both deterministic and nondeterministic TMs can be defined.
- The deterministic TM is called:

Standard TM

  - For convenience, we usually drop the standard and just call it Turing machine (TM).

- The nondeterministic one is called:

Nondeterministic TM (NTM)

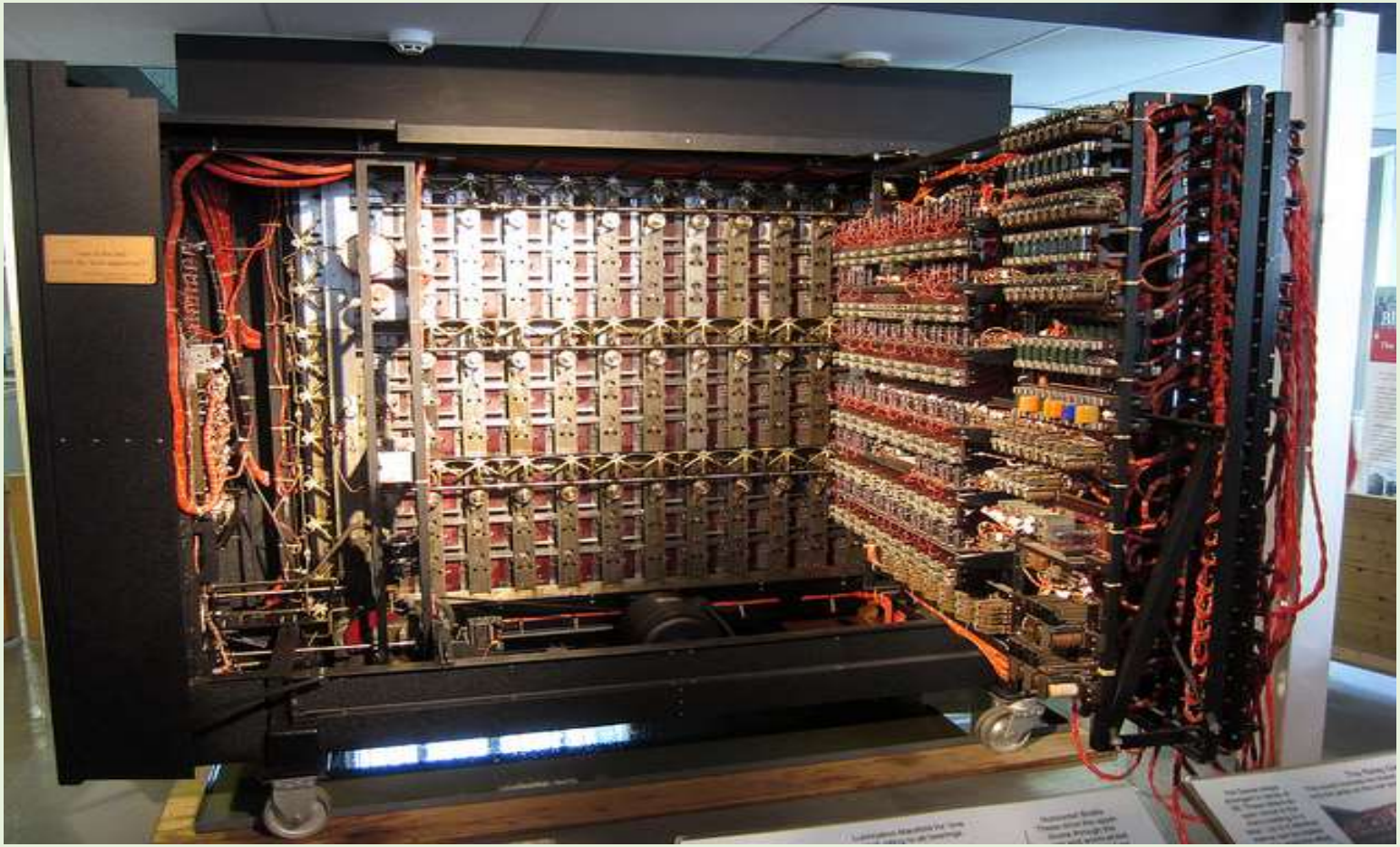
- Before introducing TMs, let's see who is Alan Turing?

Who is Turing?

- Alan Mathison Turing (1912 – 1954) born in Britain.
- He was:
  - mathematician
  - logician
  - cryptanalyst
  - theoretical biologist
- He is known as the father of the:
  - theory of computation (Computer Science Foundation)
  - artificial intelligence
- He is one of the most effective pioneering computer scientists.

Who is Turing?

- During World War II, he invented an electromechanical machine called "Bombe Machine".



Who is Turing?

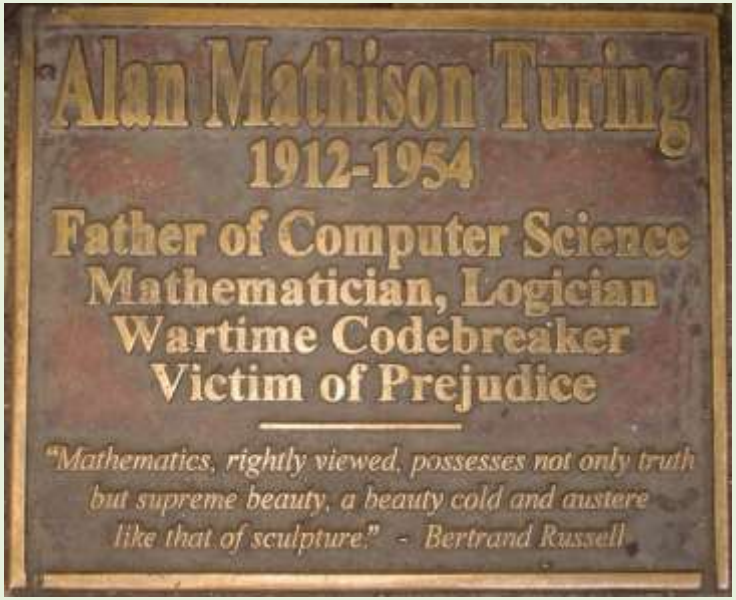
- His Bombe Machine could break Hitler's Enigma machine encryptions.

- It is said that his work shortened the war between 2 to 4 years.
- Based on some estimations, he saved 14 million lives.

- Hitler was so close to construct nuclear bomb.
- Just imagine what could happen if
  the war lasted two more years
  and Hitler could finish his nuclear bomb!

Who is Turing?

- He was prosecuted in 1952 for homosexual acts and died in 1954 when he was only 42!



- In 2013, 61 years after his death, he was granted a Royal pardon (!) by the British Queen.

Who is Turing?

- In 1966, Association for Computing Machinery (ACM) created an annual prize called "A. M. Turing Award".
- It is the highest award in computer science, given to an individual whose contribution in computer science is outstanding.
- It is called the "Nobel prize of computing".
- Since 2014, Google has been supporting the prize that is $1 million.

Who is Turing?

Documentary

- Produced by BBC: https://www.youtube.com/watch?v=GH1WYUKP3hk
- "Turing: Pioneer of the Information Age" by Stanford https://www.youtube.com/watch?v=p7Lv9GxigYU
- "Turing the Man" by ACM https://www.youtube.com/watch?v=KUaKrtF0-hQ

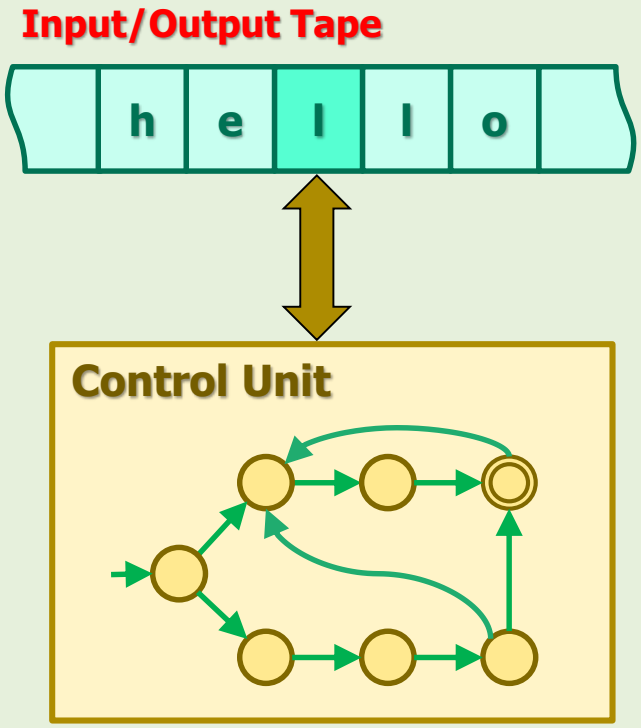
Movies

- Breaking the Code, Biography of Alan Turing (BBC 1996) https://www.youtube.com/watch?v=S23yie-779k
- The Imitation Game (2014) currently on Netflix
- Codebreaker: The Story of Alan Turing

3. TMs Building Blocks

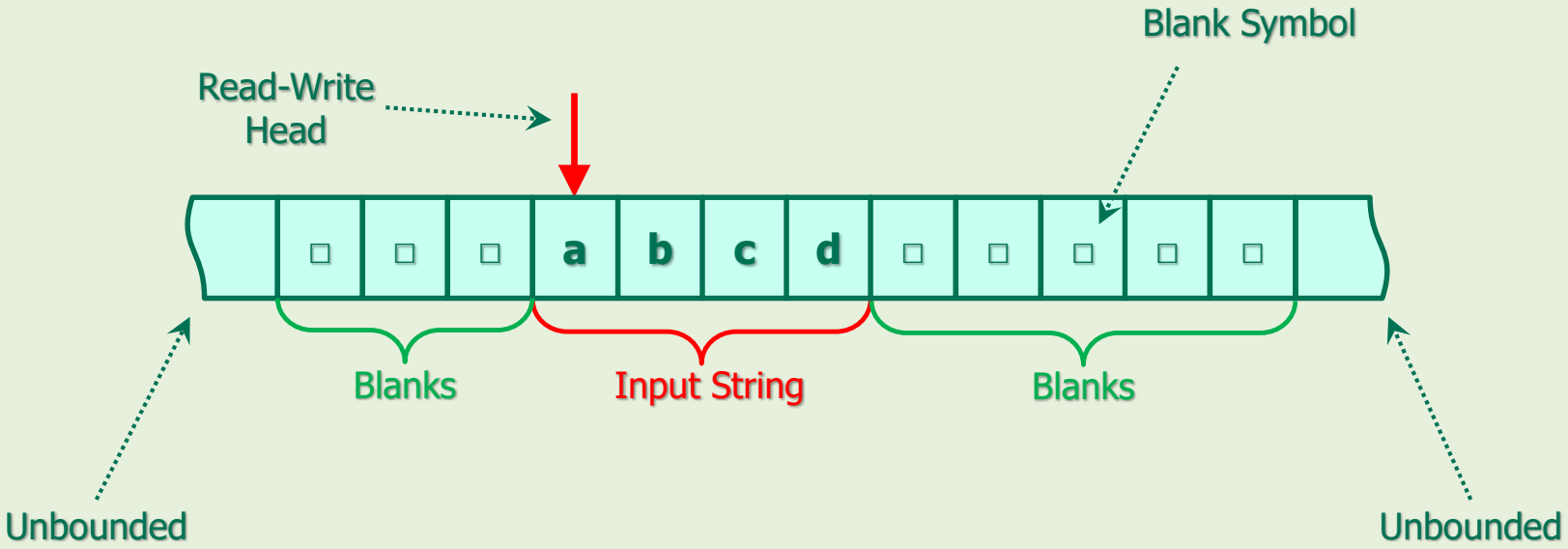
3. TMs Building Blocks

- TMs have 2 main blocks:
  1. Input / Output Tape
  2. Control Unit



- Let's see each block in detail.

3.1. Input / Output Tape: Structure

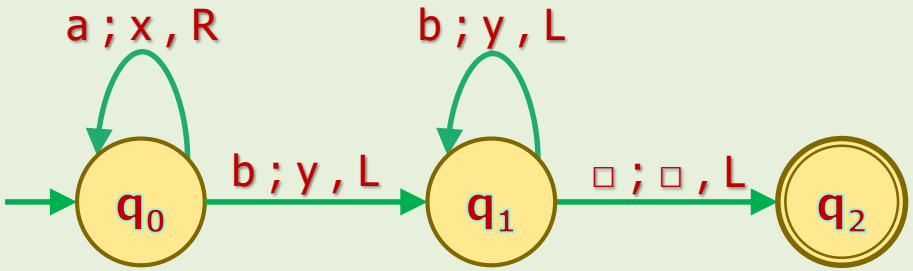


- The tape is unbounded from both sides.
- A read-write head reads a symbol, writes a symbol, and moves left or right.
- The input string can be written somewhere on the tape.
- The rest of the tape contains blank symbols '□'.

3.2. Control Unit: Structure

- The control unit of TMs look pretty much like NPDAs'.
  - They are represented by "transition graphs".

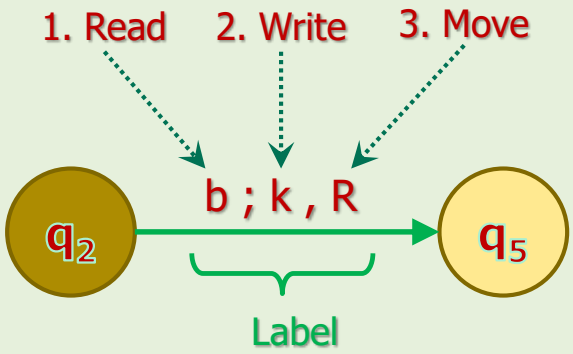
- This is an example of a TM's transition graph.



- The only difference is how the edges are labeled.

- Let's analyze a transition in detail.

3.2. Control Unit: Labels



- The label has 3 parts, delimited by semicolon and comma:
  1. The input symbol (e.g. 'b') that should be read from the tape
  2. The symbol (e.g. 'k') that should be written into the tape
  3. The move direction of the head that can be "Left" or "Right". ('L' = Left or 'R' = Right)
     - L and R are called "move symbols".

Team Formation

References

1. Linz, Peter, "An Introduction to Formal Languages and Automata, 5th ed.," Jones & Bartlett Learning, LLC, Canada, 2012
2. Kenneth H. Rosen, "Discrete Mathematics and Its Applications, 7th ed.," McGraw Hill, New York, United States, 2012
3. Michael Sipser, "Introduction to the Theory of Computation, 3rd ed.," CENGAGE Learning, United States, 2013
   ISBN-13: 978-1133187790
4. Wikimedia Commons, https://commons.wikimedia.org/wiki/Category:Animations_of_machinery
5. https://en.wikipedia.org/wiki/Turing_Award
6. https://en.wikipedia.org/wiki/Alan_Turing
7. https://www.turing.org.uk/

Appendix A: Alan Turing

Ref: https://www.awesomestories.com/asset/view/Alan-Turing-Early-Years

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Ref: https://www.histclo.com/essay/war/ww2/code/ncs/ger/ultra/ind/turn/tur-ed.html

Appendix A: Alan Turing

Ref:
https://www.exploringsurreyspast.org.uk/themes/people/scientists/alan_turing/

Walton Athletics Club, going to a race

Appendix A: Alan Turing

Ref: https://cacm.acm.org/magazines/2017/8/219602-turings-pre-war-analog-computers/abstract

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Enigma machine at Bletchley Park