San José State University
Department of Computer Science

Ahmad Yazdankhah
ahmad.yazdankhah@sjsu.edu
www.cs.sjsu.edu/~yazdankhah

Nondeterministic Finite Automata

(Part 1)

Lecture 09

Day 09/31

CS 154

Formal Languages and Computability

Spring 2019

Agenda of Day 09

- Summary of Lecture 08
- Quiz 3
- A few slides from lecture 08
- JFLAP Demo
- Lecture 09: Teaching ...
  - Nondeterministic Finite Automata (Part 1)

Summary of Lecture 08: We learned ...

DFAs

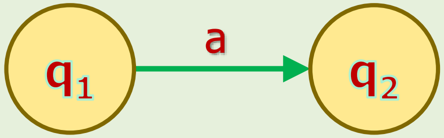
- A DFA M is defined by a quintuple:

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

- Q is ...
  - ... a finite and nonempty set of states.
- Σ is ...
  - ... a finite and nonempty set of symbols called input alphabet.
- δ is ...
  - ... called transition function and is defined as: $\delta: Q \times \Sigma \rightarrow Q$

δ is total function.

- $q_0 \in Q$ is ...
  - ... the initial state.
- $F \subseteq Q$ is ...
  - ... the set of accepting states.
- Every sub-rule like $\delta(q_1, a) = q_2$ represents a transition in transition graph.



Any question?

Summary of Lecture 08: We learned ...

DFAs

- Why total function?
  - ... because if not, in some situations, the DFA does not know where to go!
- DFAs constraint: ...
  - ... DFAs transition function must be total function.
- The consequence of this constraint is ...
  - ... every state must have an outgoing transition for every symbol of alphabet.

Any question?

NAME	Alan M. Turing		
SUBJECT	CS 154	TEST NO.	3
DATE	02/21/2019	PERIOD	1 / 2 / 3

TEST RECORD	
PART 1	123
PART 2	
TOTAL	

Your list # goes here!

Quiz 3

Use Scantron

A Few Slides from Lecture 08

Prepare Your Development Environment

JFLAP (Java Formal Language and Automata Package)

- We'll use JFLAP tool in this course to develop and test our automata.
- **Download it from Canvas**: Files/Misc/JFLAP7.1.jar
  - For uniformity, please use the copy that I provided!
- Tutorial: http://www.jflap.org/tutorial/

JFLAP Demo

- **Official website**: http://www.jflap.org/
- Official download site: http://www.jflap.org/jflaptmp/ (Don't !)
- The stable version 7.1 (Jul 27, 2018)

JFLAP Basic Features

Basic Features

- Creating states
- Creating transitions
- Defining a state as initial state or final state
- Deleting
- Shift-Enter to create multiple transitions
- Multiple running (testing your design)
- Debugging: step-by-state
- Saving machines (xml file)

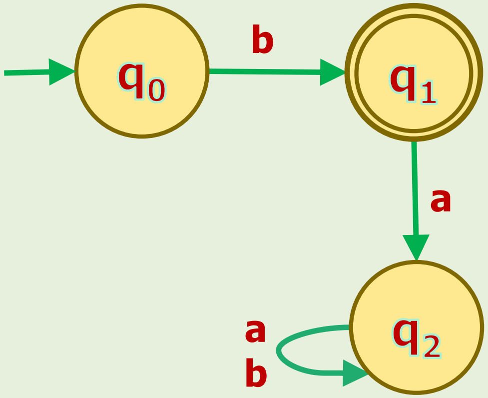
- Selecting multiple objects and moving
- Changing state's name or label
- Adding comment
- Changing edges shape
- Zoom-in and zoom-out

Nondeterministic Finite Automata (NFA)

DFAs Constraint Violations

DFAs Constraint Violation #1

- What is the problem of the following DFA over $\Sigma = \{a, b\}$?

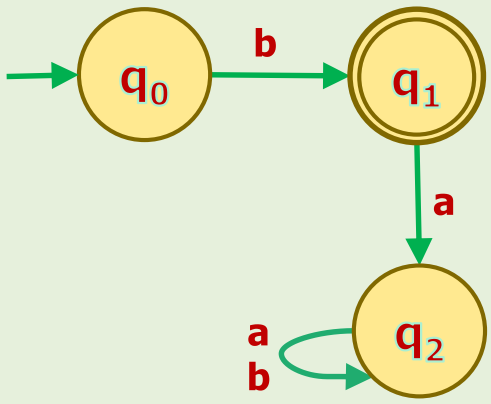


Violation

- The machine has no (zero) transition when it is in state q_0 and the input is a!
  - There is more like this in this graph, what are they?
- In other words, there are some timeframes that the machine does NOT KNOW WHERE TO GO?

DFAs Constraint Violation #1

- What is the value of $\delta (q_0, a)$?
  - $\delta (q_0, a)$ = "Undefined"

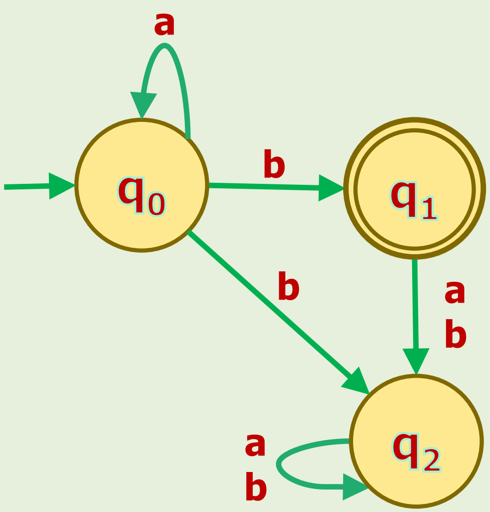


- What type of function is the transition function of this machine?
- Partial function

- So, the machine is NOT a DFA because it violates DFAs constraint!

DFAs Constraint Violation #2

- What is the problem of the following DFA over $\Sigma = \{a, b\}$?



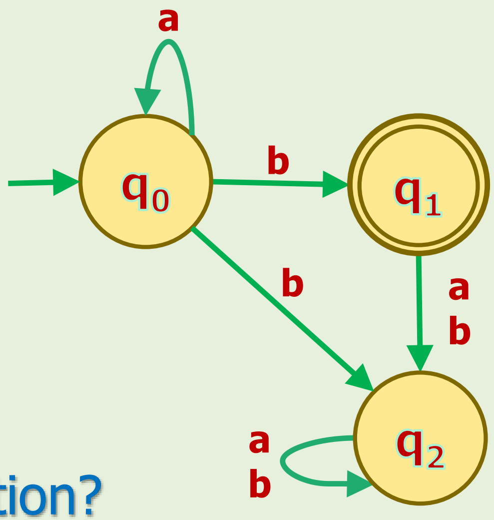
Violation

- The machine has more than one transition when it is in state q_0 and the input is b!

- In other words, there are some timeframes that the machine does NOT KNOW WHERE TO GO?
  - Because there are more than one choice!

DFAs Constraint Violation #2

- What is the value of $\delta\ (q_0, b)$?
  - $\delta\ (q_0, b) = \{q_1\ , q_2\}$
  - The range has more than one value!
  - So, we have to put them in a set of Qs.



- What type of function is the transition function?
  - It is NOT a regular function because it violates the definition of function.
  - It is called "multifunction" (aka multivalued function) in math.

- So, the machine is not a DFA because it violates the DFAs constraint!

DFAs Constraint Violations Summary

- **Violation #1**: There are some timeframes that the machine has no (zero) transition.
  - The transition function is NOT total function.

- **Violation #2**: There are some timeframes that the machine has more than one transition.
  - The transition function is NOT a regular function.
  - It is multifunction (aka multivalued function).

- Let's relax the DFAs constraint and define a new class of machines!
- We are going to have a new class of machines that these violations are legal.

Let's Relax the DFAs Constraint!

- Recall that DFAs' transition function is defined as:

$$\delta: Q \times \Sigma \rightarrow Q$$

δ is total function.

- To accommodate those two violations,
  we change the RANGE of the function to a set.
- In this way, the range can have zero, one, or more states.
- In other words, the range of this function is a set of Qs.
- We already know that 2^Q is the power set of Q and
  it contains all subsets of Q.
- Therefore, we change the range from Q to 2^Q.

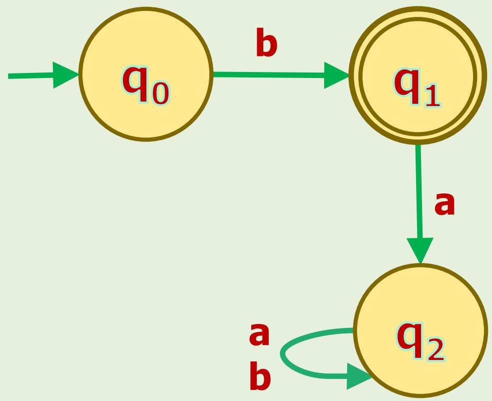
$$\delta: Q \times \Sigma \rightarrow 2^Q$$

- Let's take some examples.

Relaxed Transition Function Examples

Example 1

- Write the rule of the following transition graph over $\Sigma = \{a, b\}$.



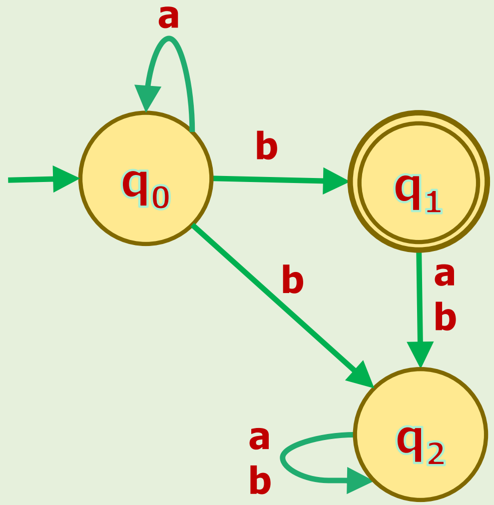
Solution

$$\begin{cases} \delta(q_0, a) = \{\,\} \\ \delta(q_0, b) = \{q_1\} \\ \delta(q_1, a) = \{q_2\} \\ \delta(q_1, b) = \{\,\} \\ \delta(q_2, a) = \{q_2\} \\ \delta(q_2, b) = \{q_2\} \end{cases}$$

Relaxed Transition Function Examples

Example 2

- Write the rule of the following transition graph over $\Sigma = \{a, b\}$.



Solution

$$\begin{cases} \delta(q_0, a) = \{q_0\} \\ \delta(q_0, b) = \{q_1, q_2\} \\ \delta(q_1, a) = \{q_2\} \\ \delta(q_1, b) = \{q_2\} \\ \delta(q_2, a) = \{q_2\} \\ \delta(q_2, b) = \{q_2\} \end{cases}$$

References

1. Linz, Peter, "An Introduction to Formal Languages and Automata, 5th ed.," Jones & Bartlett Learning, LLC, Canada, 2012
2. Michael Sipser, "Introduction to the Theory of Computation, 3rd ed.," CENGAGE Learning, United States, 2013
ISBN-13: 978-1133187790