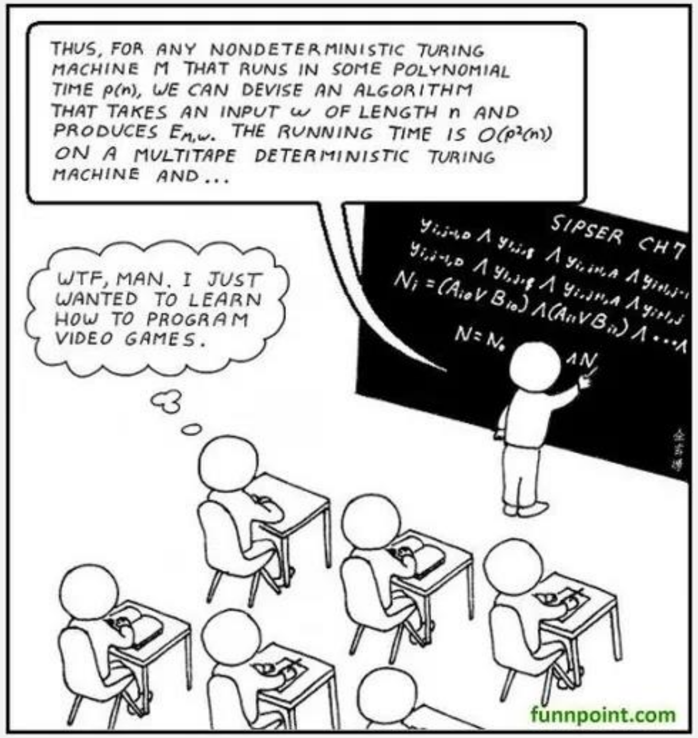


Nondeterminism

Monday Sept 21, 2020

Hw1 questions?

How to Code (Recap)

Anonymous Scale 2 17 hours ago

Just to add, I do agree that coding is difficult, but I think what is meant by that is translating the math into c...

trans...

just t...

But t...

helpfu...

> Since 2011, engineers at Amazon Web Services (AWS) have been using formal specification and model checking to help solve difficult design problems in critical systems. This paper describes our motivation

> We found what we were looking for in TLA+ [4], a formal specification language. TLA+ is based on simple discrete math, i.e. basic set theory and predicates, with which all engineers are familiar. A TLA+

"Translating the math into code" is **exactly** the definition of "knowing hov...

Typically, the "math" is called a "specification" or "requirements", and it's combination of vague English and actual math, just like the hw descriptio... near as clear and detailed as my writing of course).

And from this specification you will be expected to ship a fully working pr... testing with an autograder either) at the end of a tight schedule.

For non-software industry programming jobs, you'll get even less directio...

Again, I say this not to belittle or discourage, but to try to prepare you all futures as best I can. My door is always open to anyone who wants to ta...

it applies an **activation function** g

ML specification:

$$a_i = g(in_i) = g\left(\sum_{j=0}^{n} W_{j,i} a_j\right) .$$

●●●○○ Sprint LTE 9:22 AM 75%

Messages **the client** Details

hey I'll pay you $100k to develop my social media app

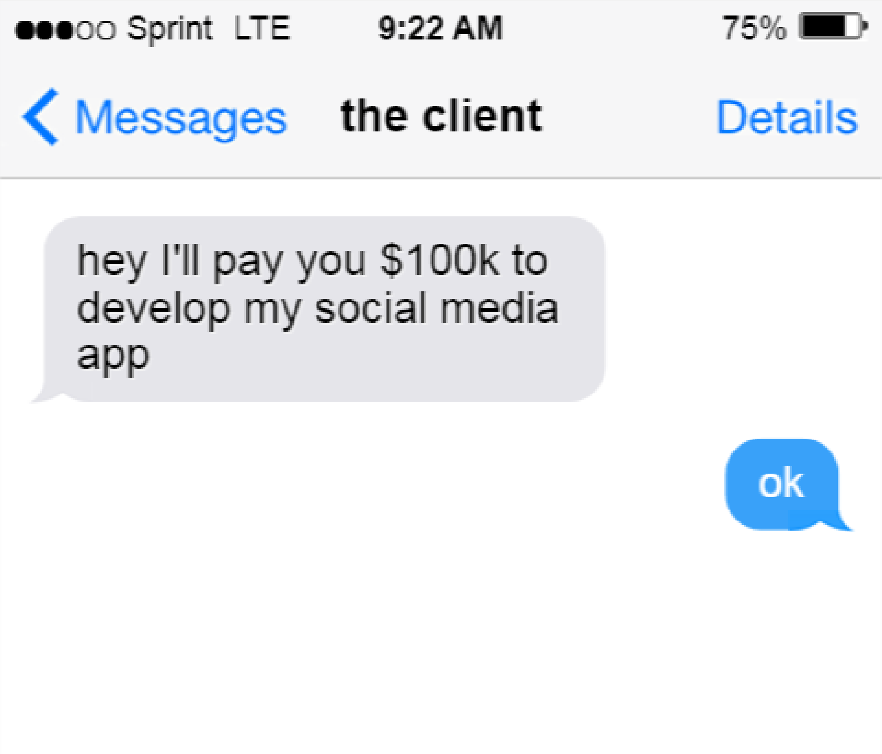
ok

How to Code: Step 1, Data Defs

Math vs Representation, Examples

Abstract Math Concept	Possible Data Representation
Numbers	Int, BigInt, float, double
Set	List, array, tree
Tuple (i.e., a small finite set)	Struct, object, list
Function, i.e., a set of pairs	Function, dict, map, hash, tree
Finite automata	XML str, <your choice here>

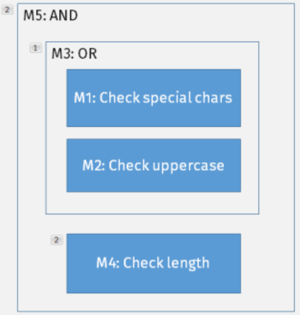
- Design your Data Definitions
- Ie, representation of real-world thing(s) your program operates on
- A `User` is a `struct` containing
  - `String name`
  - `String screenname`
  - `Int internal_ID`
  - `List<Post> posts`
  - `List<User> followers`
- A `Post` is a (140 character) `String`



How to Code: Step 2, Data Operations

- Design Operations for your data from step 1
- `Users` need to:
  - `Post()`
  - `Delete()`
  - `Like()`
  - `Follow()`
- A good specification/requirement (like the hw) gives this to you

How to Code: <u>Step 3</u>, start coding



Want to be able to easily <u>combine</u> finite automata machines

To keep combining operations must be **closed**!

- <u>Implement</u> the operations, **step-by-step**
- Start with one tiny, simple, observable piece of code
  - E.g., `read` input; `print` as output
- Add more code slowly, step-by-step
  - Should be guided by your data definitions and operations
  - E.g., read input as xml file
    - Then Parse xml file, print states
    - Then Parse transitions, then construct DFA object
  - Make sure the program changes how you expect <u>at each step</u>

How to Code: Step 4, testing

- Build up to a **small** test case
  - The Hw always gives one

- Eventually, create more tests
  - You write tests, right?
  - Each should test different parts of your program
  - 100% code coverage is minimum requirement
  - Easy way to test union problem?
    - Use you solution from parts 1-3 of the hw

How to Code: Step 5, debugging

FAQ: Is the autograder broken?

No, the autograder is not broken

- If the autograder is crashing, then your program is broken

- The autograder is **not** a debugging tool
  - So don’t use it to debug
  - Debugging is solely your job

- The autograder’s only obligation: report your grade score

- <u>However</u>, all your errors are reported in the summary section

How to Code: Step 5, debugging

- If you followed steps 1-4, then debugging should be obvious
  - Program in small, composable pieces (ie, fns, methods, classes)

- Still have big chunk of code fails, what to do?
  - Narrow it down.
  - Do something observable, eg, `print("made it here")`, halfway
  - Keep narrowing down (binary search) until you find the right line

Final notes about coding

- It’s a requirement for the course
- Coding hws will likely end around hw4 (maybe)
- Remember: lowest hw score dropped
- Can still do well in the course without writing any code

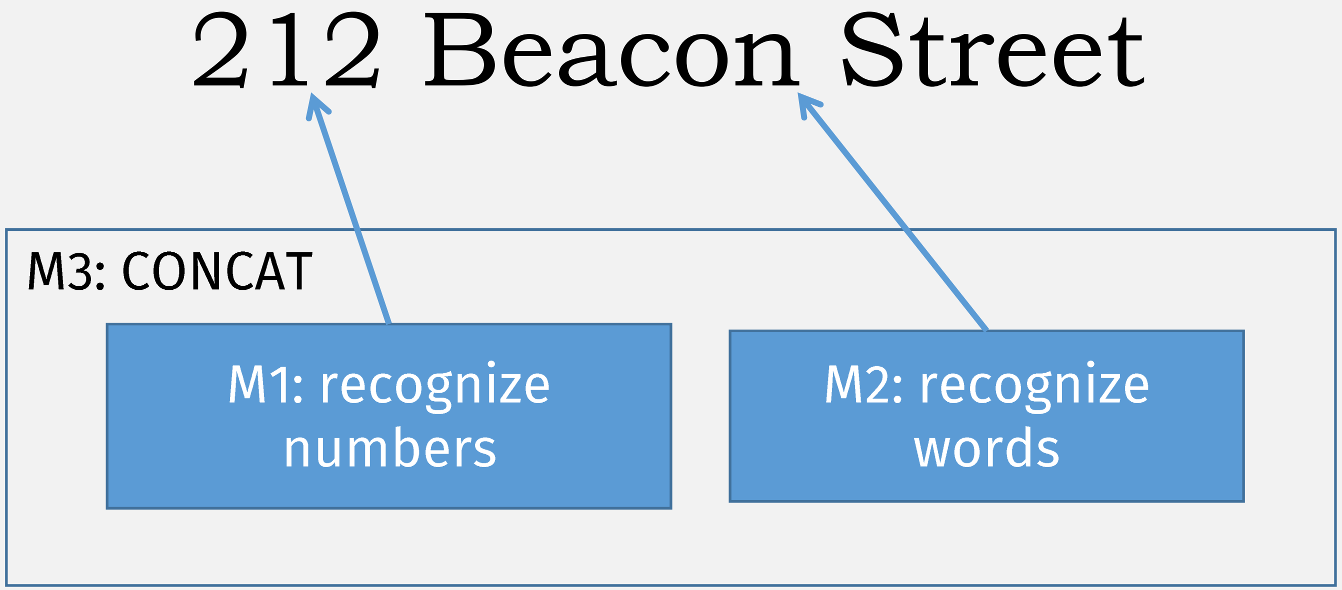
Nondeterminism

Big Picture Road Map

- We ultimately want to prove:
  - Regular Languages ⇔ Regular Expressions
- First, we need to show these operations are closed for reglangs:
  - Union (done, last class!)
  - Concatentation
  - Kleene star
- To prove the last 2, we need non-determinism and NFAs!
  - We know Regular Languages ⇔ DFAs (by definition)
  - But are Regular Languages ⇔ NFAs???

Last time: Concatenation Operation

- Example: Want to match street addresses



Last time: Concatenation Closed?

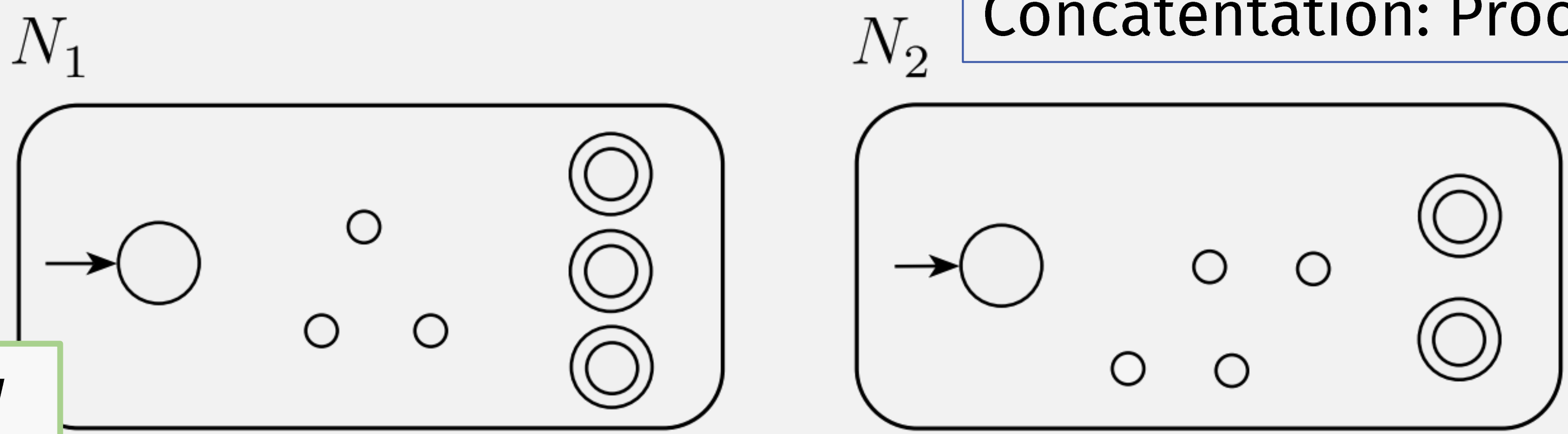
THEOREM 1.26

The class of regular languages is closed under the concatenation operation.

In other words, if A_1 and A_2 are regular languages then so is $A_1 \circ A_2$.

- Construct a new machine **M**?
  - using DFA $\mathbf{M_1}$ (which recognizes A_1),
  - and DFA $\mathbf{M_2}$ (which recognizes A_2)

Concatentation: Proof by construction



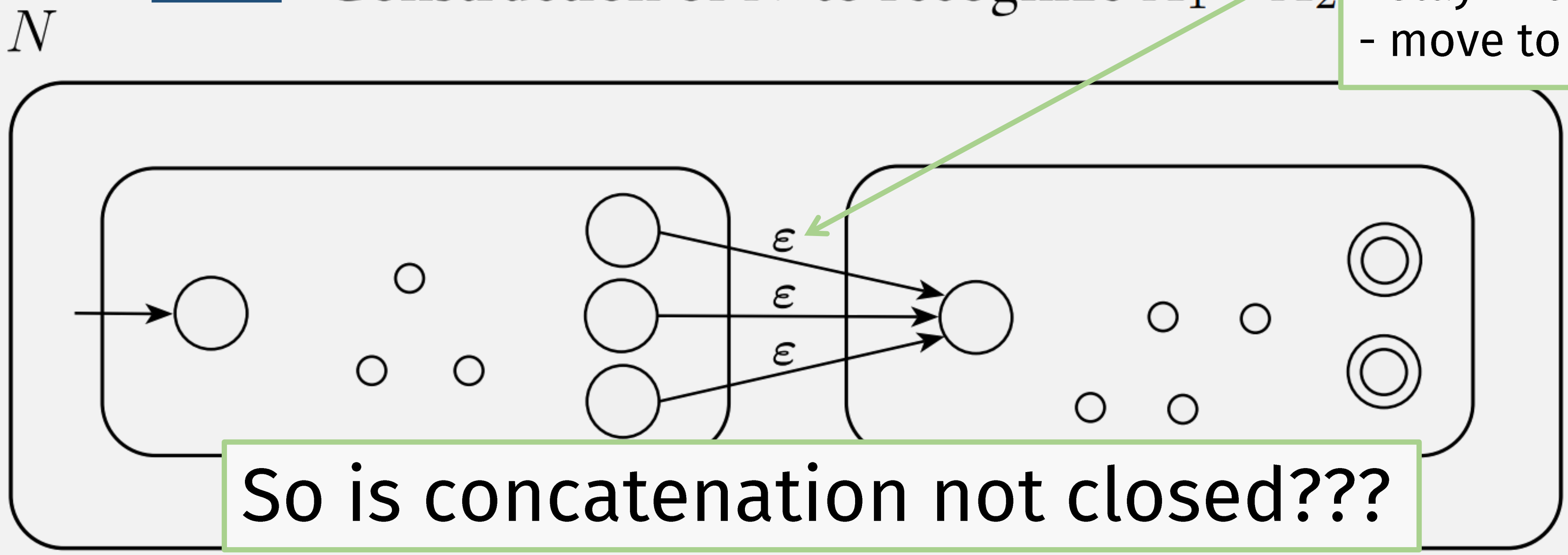
N is a new kind of machine, an NFA!

Let N_1 recognize A_1, and N_2 recognize A_2.

Want: Construction of N to recognize $A_1 \circ A_2$

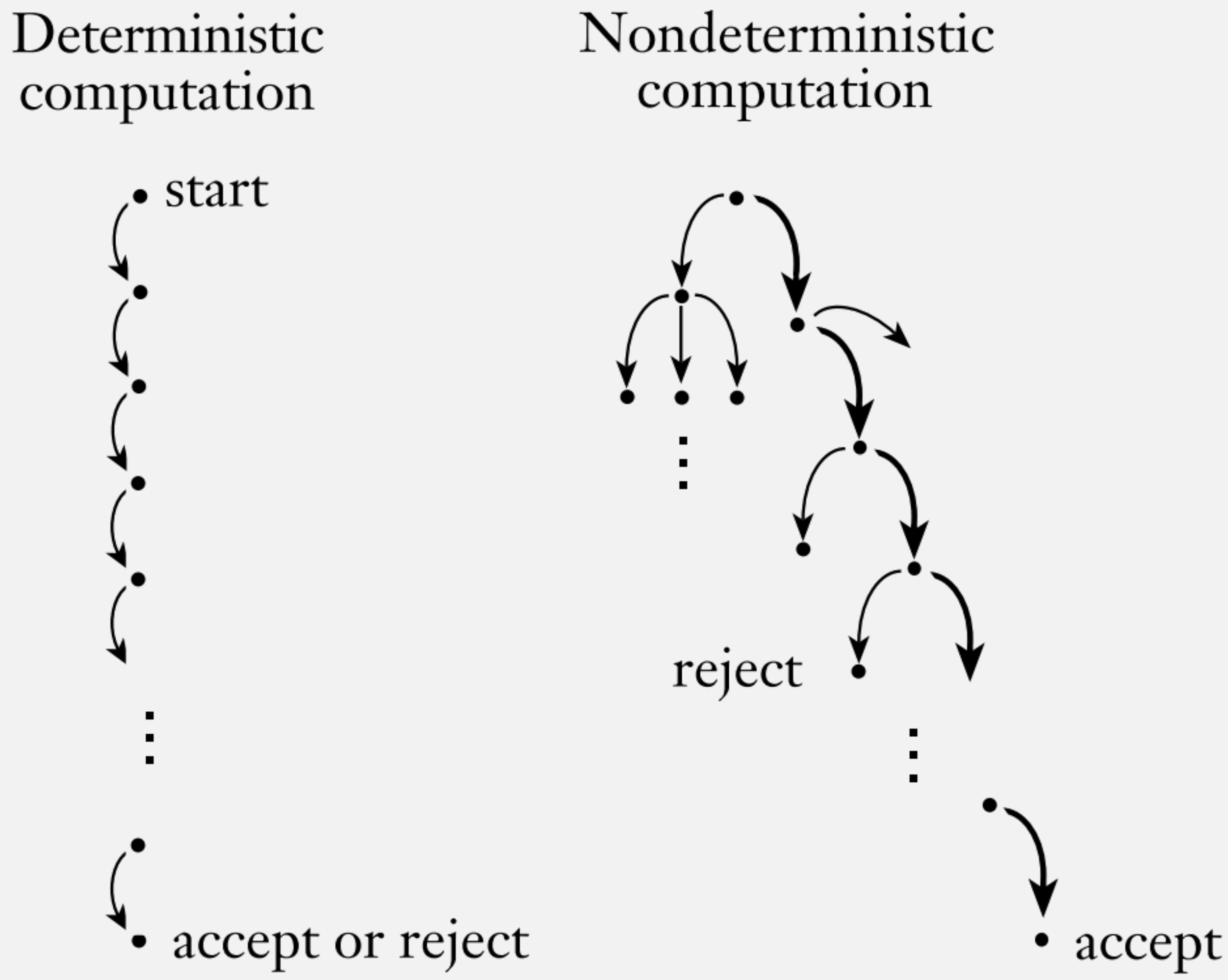
ε = empty string = no input

So N can:
- stay in current state **and**
- move to next state

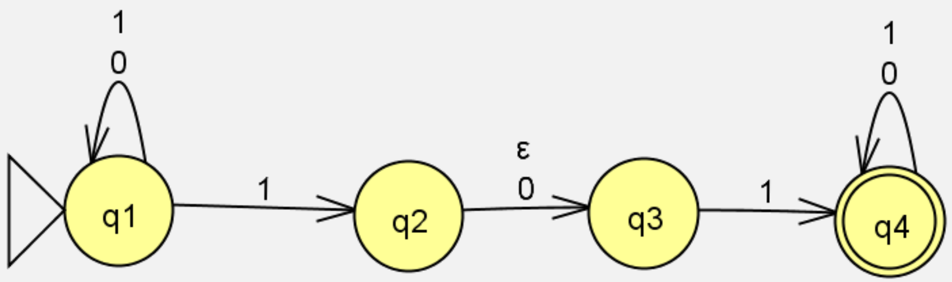


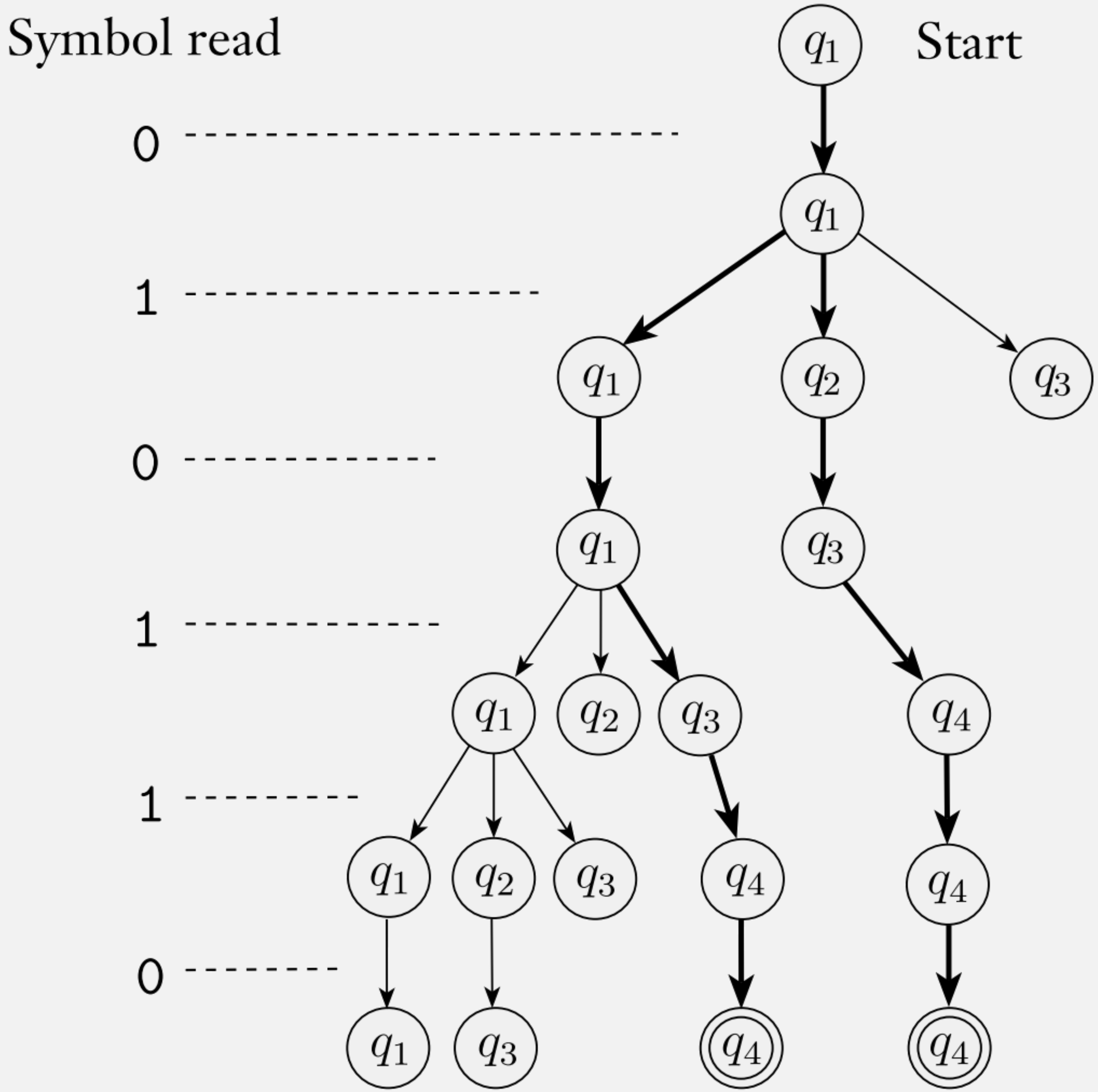
So is concatenation not closed???

NFA = Nondeterministic Finite Automata



Example fig1.27 (JFLAP demo): 010110




Symbol read
Start
0
1
0
1
1
0

Nondeterministic machine can be in multiple states at once

DEFINITION 1.37

A ***nondeterministic finite automaton*** is a 5-tuple $(Q, \Sigma, \delta, q_0, F)$, where

1. Q is a finite set of states,
2. Σ is a finite alphabet,
3. $\delta \colon Q \times \Sigma_\varepsilon \longrightarrow \mathcal{P}(Q)$ is the transition function,
4. $q_0 \in Q$ is the start state, and
5. $F \subseteq Q$ is the set of accept states.

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Power Sets

- A power set is the set of all subsets of a set
- Example: `S = {a,b,c}`
- Power set of S =
  - `{{},{a},{b},{c},{a,b},{a,c},{b,c},{a,b,c}}`

Formal Definition of "Computation"

- DFA:

M ***accepts*** w if a sequence of states $r_0, r_1, \ldots, r_n$ in Q exists with three conditions:

1. $r_0 = q_0$,
2. $\delta(r_i, w_{i+1}) = r_{i+1}$, for $i = 0, \ldots, n-1$, and
3. $r_n \in F$.

- NFA:

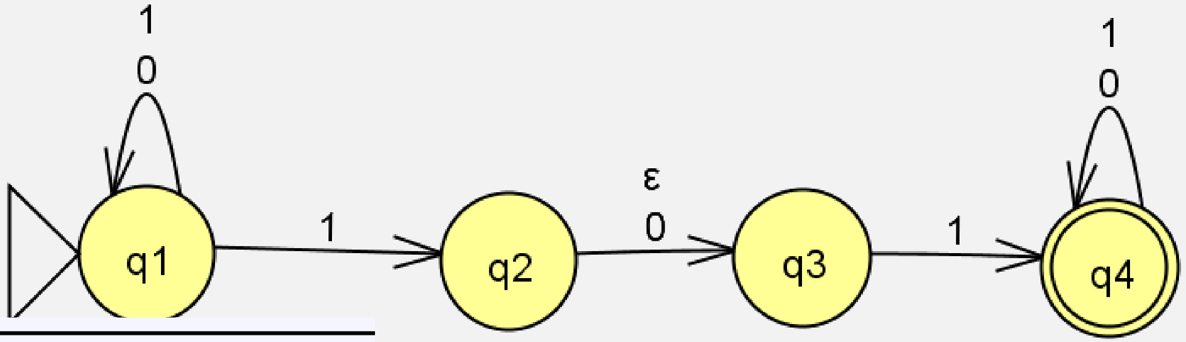
N ***accepts*** w if a sequence of states $r_0, r_1, \ldots, r_m$ exists in Q with three conditions:

1. $r_0 = q_0$,
2. $\boxed{r_{i+1} \in \delta(r_i, y_{i+1})}$, for $i = 0, \ldots, m-1$, and
3. $r_m \in F$.

Requires only one path to an accept state in the computation tree

In-class exercise

- Come up with a formal description of the following NFA:



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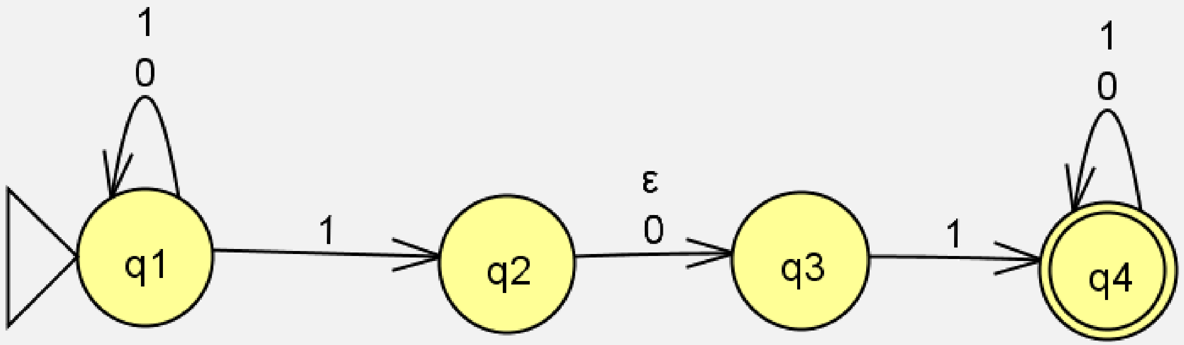
The formal description of N_1 is $(Q, \Sigma, \delta, q_1, F)$, where

1. $Q = \{q_1, q_2, q_3, q_4\}$,
2. $\Sigma = \{0,1\}$,
3. δ is given as

	0	1	ε
q_1	$\{q_1\}$	$\{q_1, q_2\}$	$\emptyset$
q_2	$\{q_3\}$	$\emptyset$	$\{q_3\}$
q_3	$\emptyset$	$\{q_4\}$	$\emptyset$
q_4	$\{q_4\}$	$\{q_4\}$	$\emptyset$,

4. q_1 is the start state, and
5. $F = \{q_4\}$.



So is concat not closed for regular langs?

- Concat produces an NFA

> A language is called a ***regular language*** if some DFA recognizes it.

- Concat is closed!
- Because **NFAs also recognize regular languages**!
  - But we must prove it!
- To show concatenation is closed, we must prove
  - NFAs ⇔ regular languages

How to prove the theorem: X ⇔ Y

- X⇔Y = “X if and only if Y” = X iff Y = X <=> Y
- Proof at minimum has 2 parts:

1. => if X, then Y
   - i.e., assume X, then use it to prove Y
   - “forward” direction
2. <= if Y, then X
   - i.e., assume Y, then use it to prove X
   - “reverse” direction

Proving NFAs recognize regular langs

- *<u>Theorem</u>*:
  - A language A is regular if and only if some NFA N recognizes it.

- Must prove:
  - => If A is regular, then some NFA N recognizes it
    - Easy
    - <u>We know</u>: if A is regular, then a **DFA** recognizes it.
    - Easy to convert DFA to an NFA! (how?)
  - <= If an NFA N recognizes A, then A is regular.
    - Hard
    - Idea: Convert NFA to DFA

Need a way to convert NFA -> DFA

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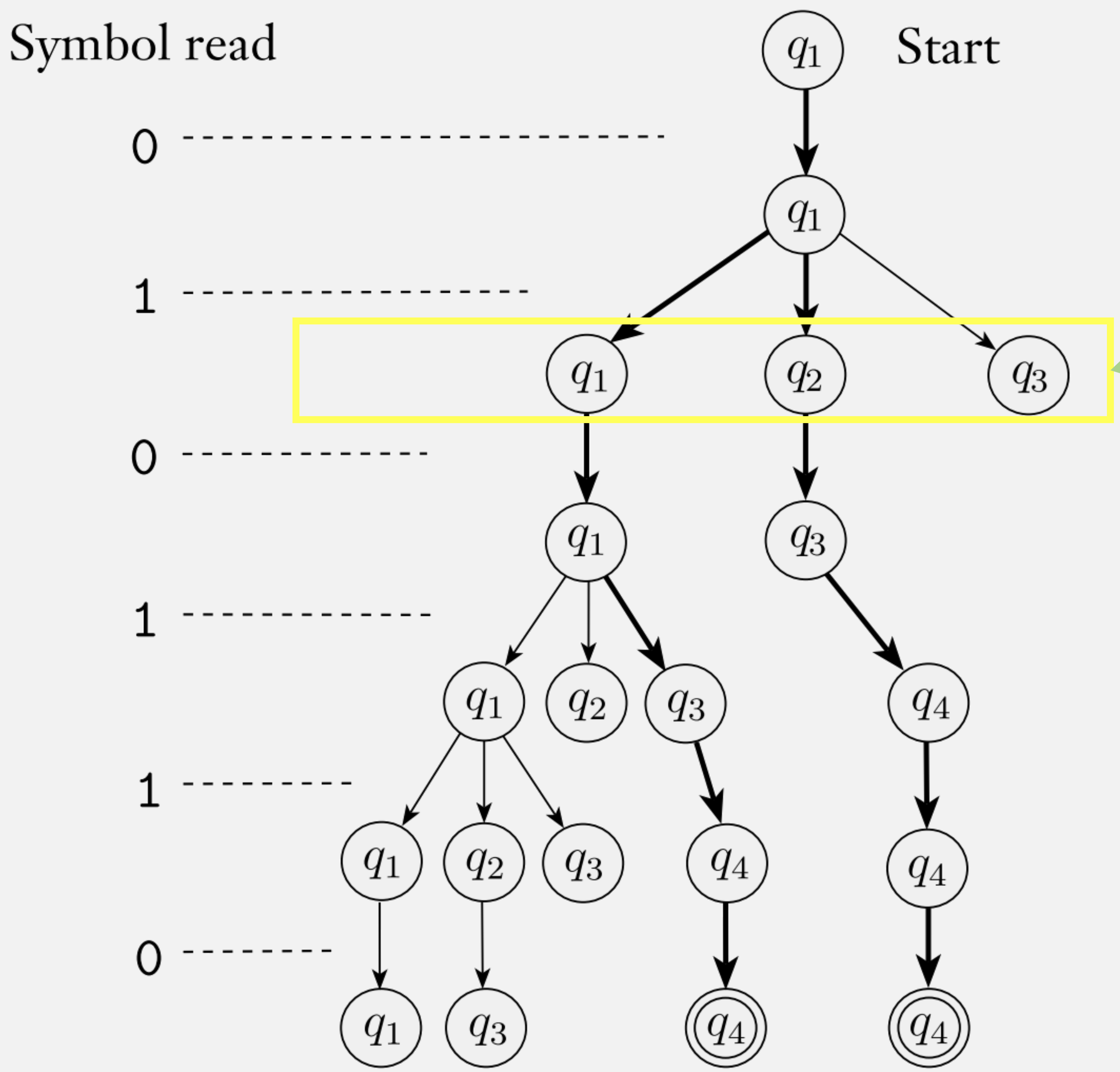
Proof idea:
Each "state" of the DFA must be a set of states in the NFA



In a DFA, all these states at each step must be only **one** state

So design a state in the converted DFA to be a **set of NFA states**!

Next time: Convert NFA -> DFA

- Let NFA N = $(Q, \Sigma, \delta, q_0, F)$
- Then equivalent DFA M has states Q' = $\mathcal{P}(Q)$ (power set of Q)
- (implement for hw2)

Check-in Quiz 9/21

On gradescope

End of Class Survey 9/21

See course website