CSE 311

Foundations of Computing I

* All slides are a combined effort between previous instructors of the course

Building Precedence in Arithmetic Expressions

- **E** – expression (start symbol)
- **T** – term **F** – factor **I** – identifier **N** - number

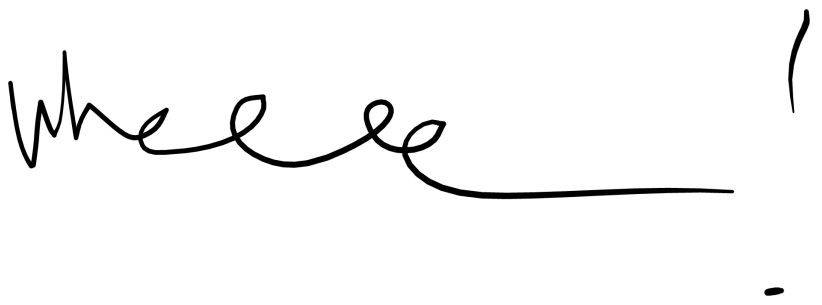
E → **T** | **E**+**T**

T → **F** | **F**∗**T**

F → (**E**) | **I** | **N**

I → x | y | z

N → 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9



Backus-Naur Form (The same thing...)

BNF (Backus-Naur Form) grammars

- Originally used to define programming languages
- Variables denoted by long names in angle brackets, e.g.

  <identifier>, <if-then-else-statement>, <assignment-statement>, <condition>

  ::= used instead of →

BNF for C

```
statement:
  ((identifier | "case" constant-expression | "default") ":")*
  (expression? ";" |
   block |
   "if" "(" expression ")" statement |
   "if" "(" expression ")" statement "else" statement |
   "switch" "(" expression ")" statement |
   "while" "(" expression ")" statement |
   "do" statement "while" "(" expression ")" ";" |
   "for" "(" expression? ";" expression? ";" expression? ")" statement |
   "goto" identifier ";" |
   "continue" ";" |
   "break" ";" |
   "return" expression? ";"
  )

block: "{" declaration* statement* "}"

expression:
  assignment-expression%

assignment-expression: (
    unary-expression (
      "=" | "*=" | "/=" | "%=" | "+=" | "-=" | "<<=" | ">>=" | "&=" |
      "^=" | "|="
    )
  )* conditional-expression

conditional-expression:
  logical-OR-expression ( "?" expression ":" conditional-expression )?
```

Parse Trees

Back to middle school:

<sentence>::=<noun phrase><verb phrase>

<noun phrase>::==<article><adjective><noun>

<verb phrase>::=<verb><adverb>|<verb><object>

<object>::=<noun phrase>

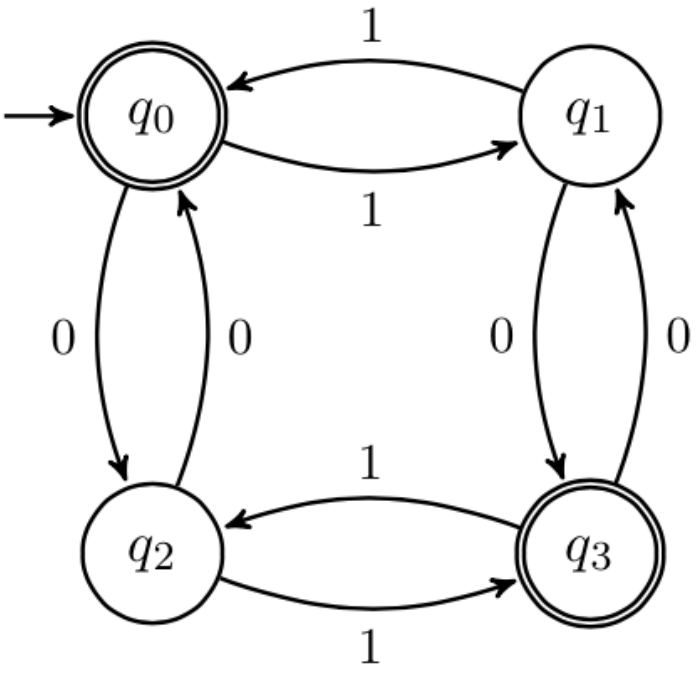
Parse:

The yellow duck squeaked loudly

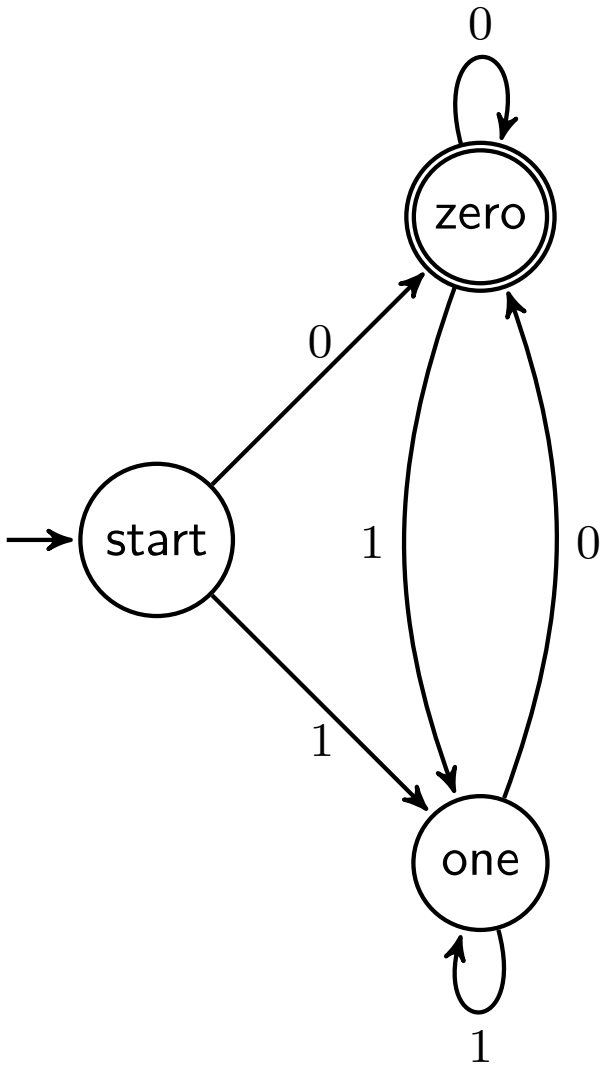
The red truck hit a parked car

CSE 311: Foundations of Computing

Lecture 20: Finite State Machines (DFAs)



A Weird Sort of Programming!



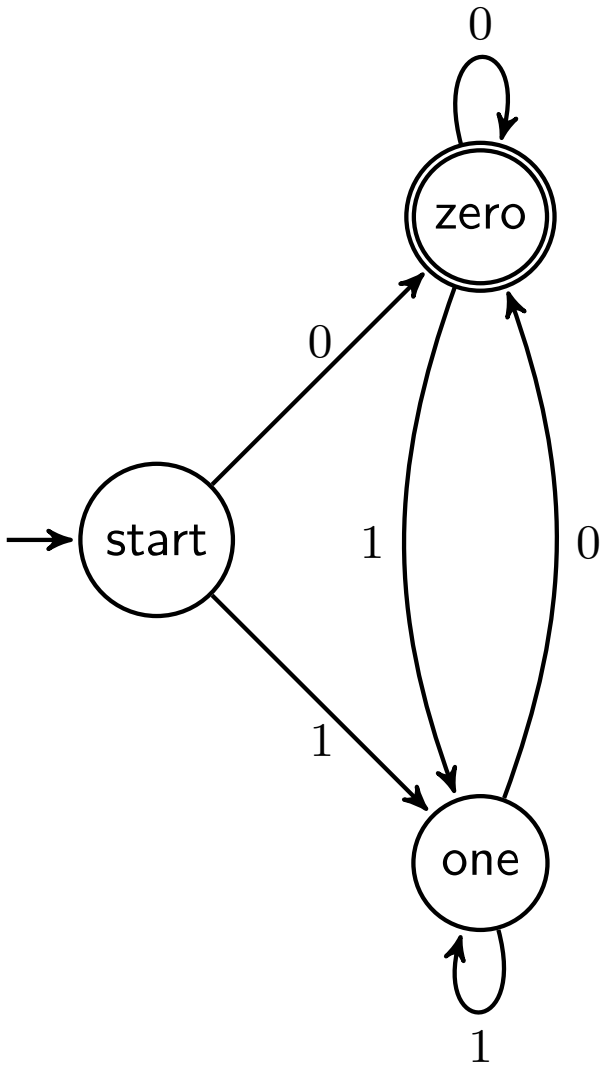
What does this "thing" do?

Take a guess!

If you had to give this "method" a name, what would it be?

boolean isEven (String b)

A Weird Sort of Programming!



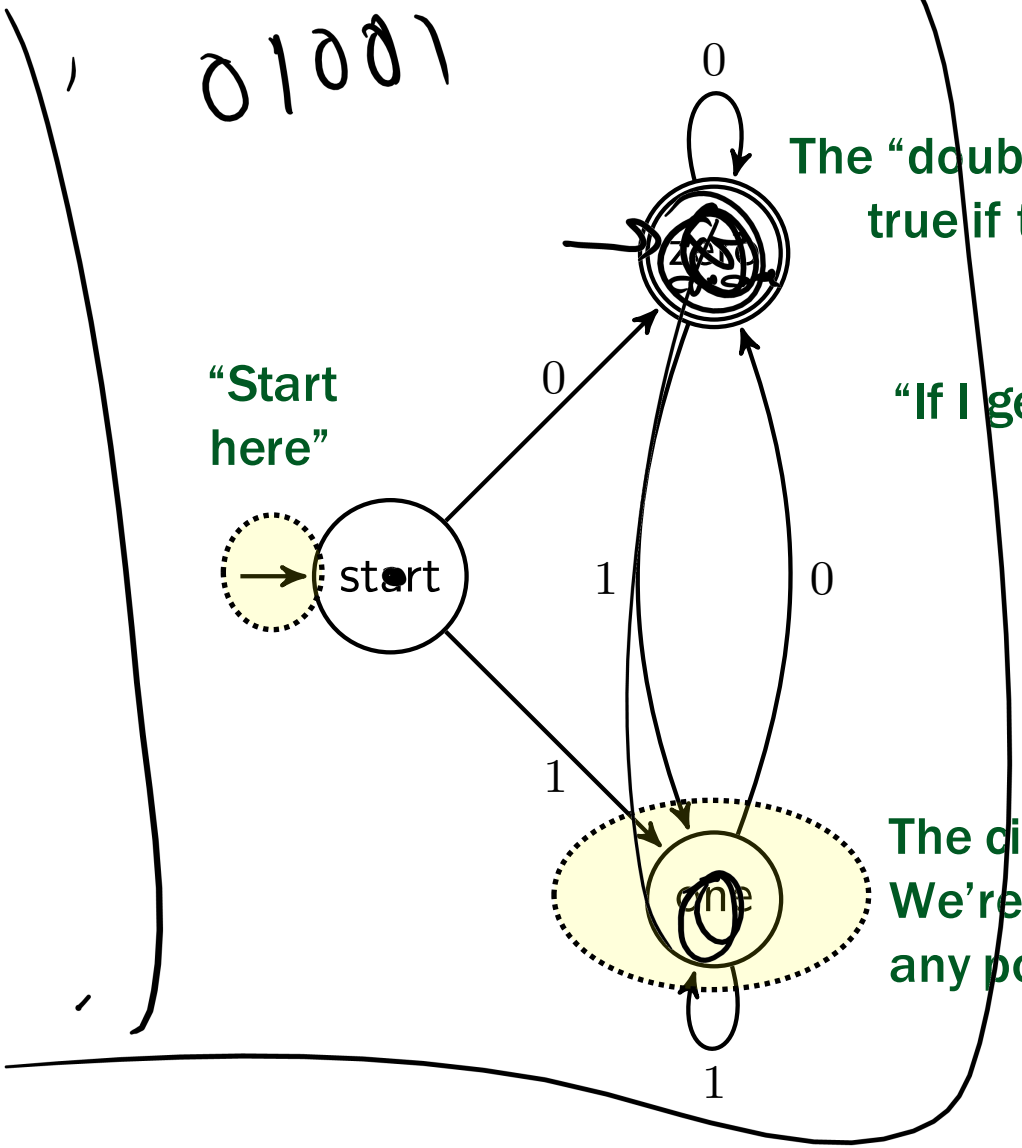
What does this "thing" do?

Take a guess!

If you had to give this "method" a name, what would it be?

```
boolean isEven(binary s)
```

Finite State Machines ("DFAs")



The "double circle" means "return true if the input ends here"

"Start here"

"If I get X, follow the arrow..."

The circles are called "states" We're only in a single state at any point in time...

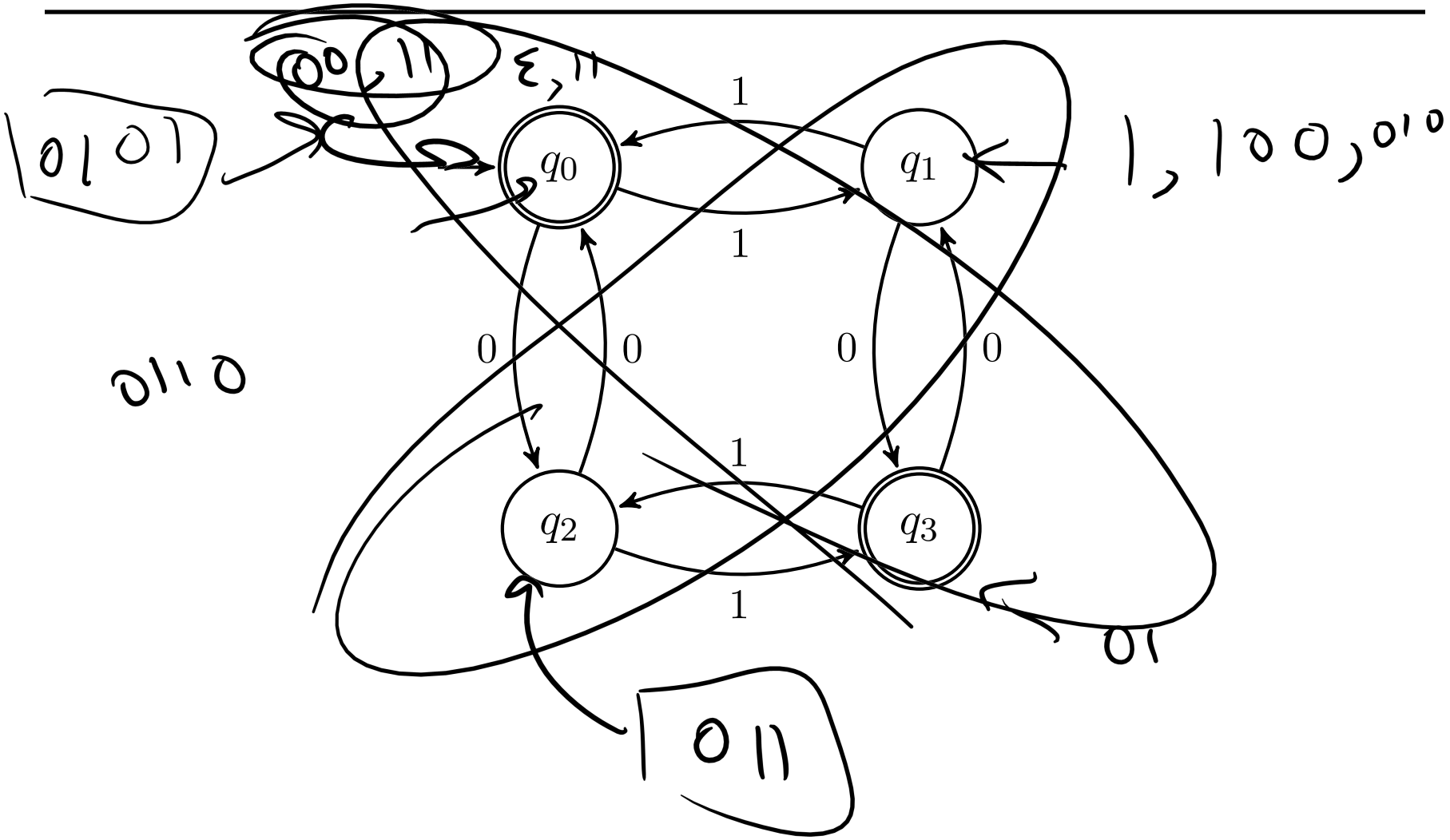
Applications of FSMs (a.k.a. finite automata)

- Implementation of regular expression matching in programs like `grep`
- Control structures for sequential logic in digital circuits
- Algorithms for communication and cache-coherence protocols
  - Each agent runs its own FSM
- Design specifications for reactive systems
  - Components are communicating FSMs

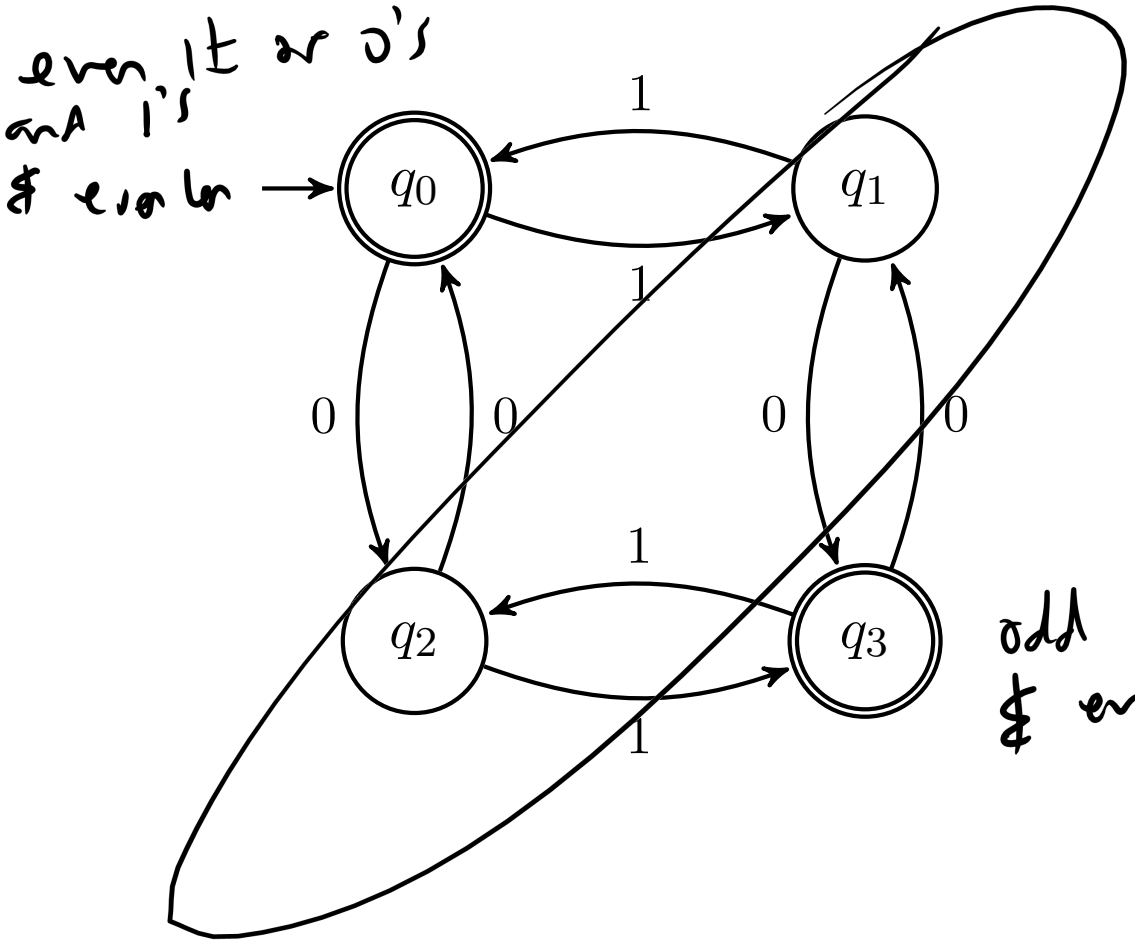
Applications of FSMs (a.k.a. finite automata)

- Formal verification of systems
  - Is an unsafe state reachable?
- Computer games
  - FSMs provide worlds to explore
- Minimization algorithms for FSMs can be extended to more general models used in
  - Text prediction
  - Speech recognition

What language does this machine recognize?

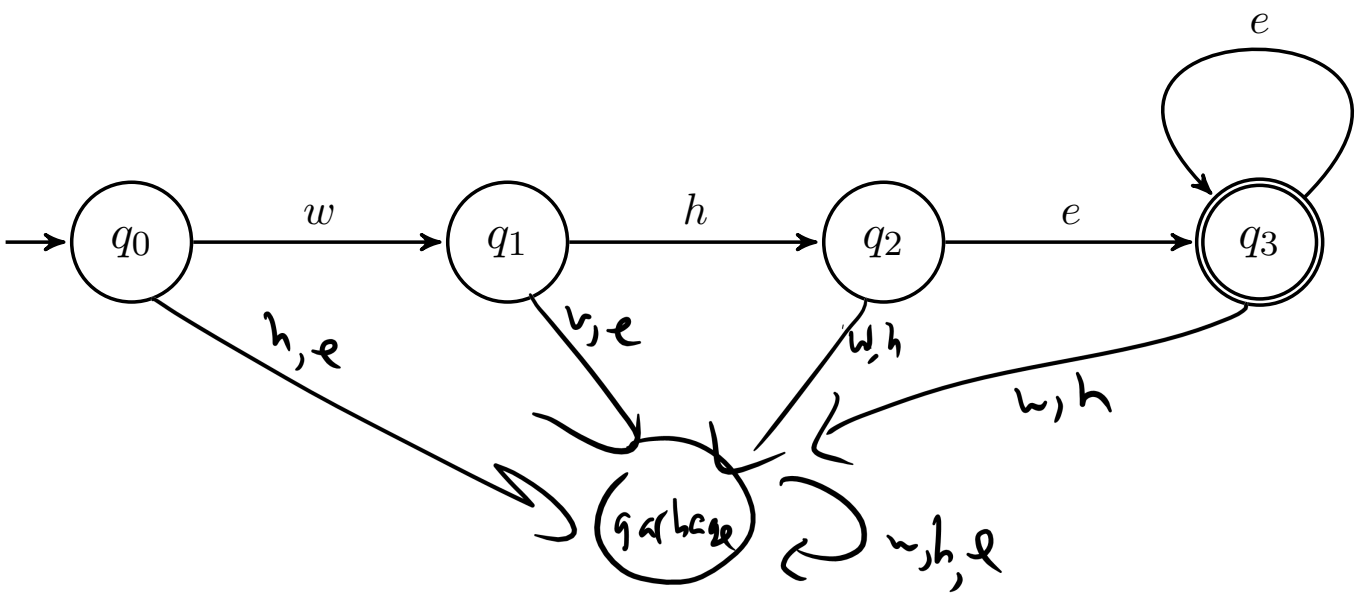


What language does this machine recognize?



All binary strings with even length

Why is this not a DFA? Fix it!



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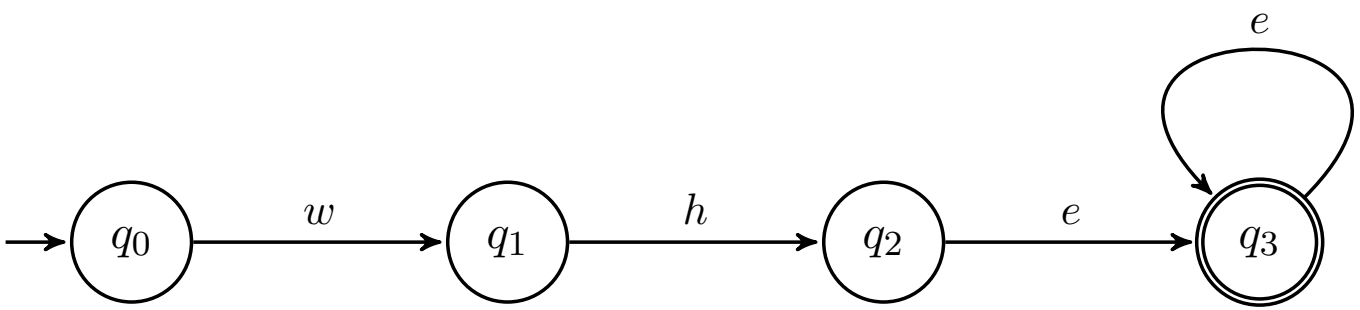
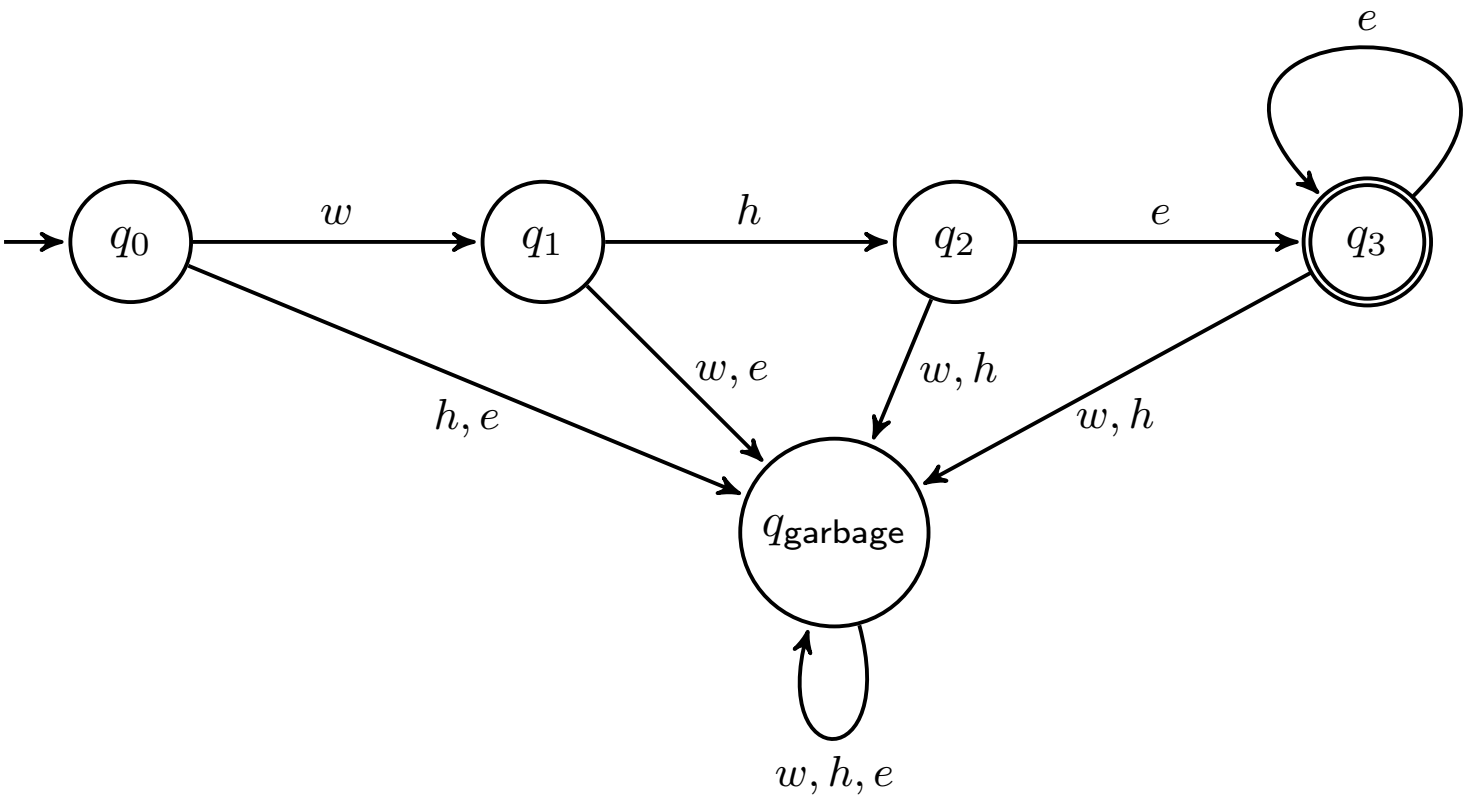


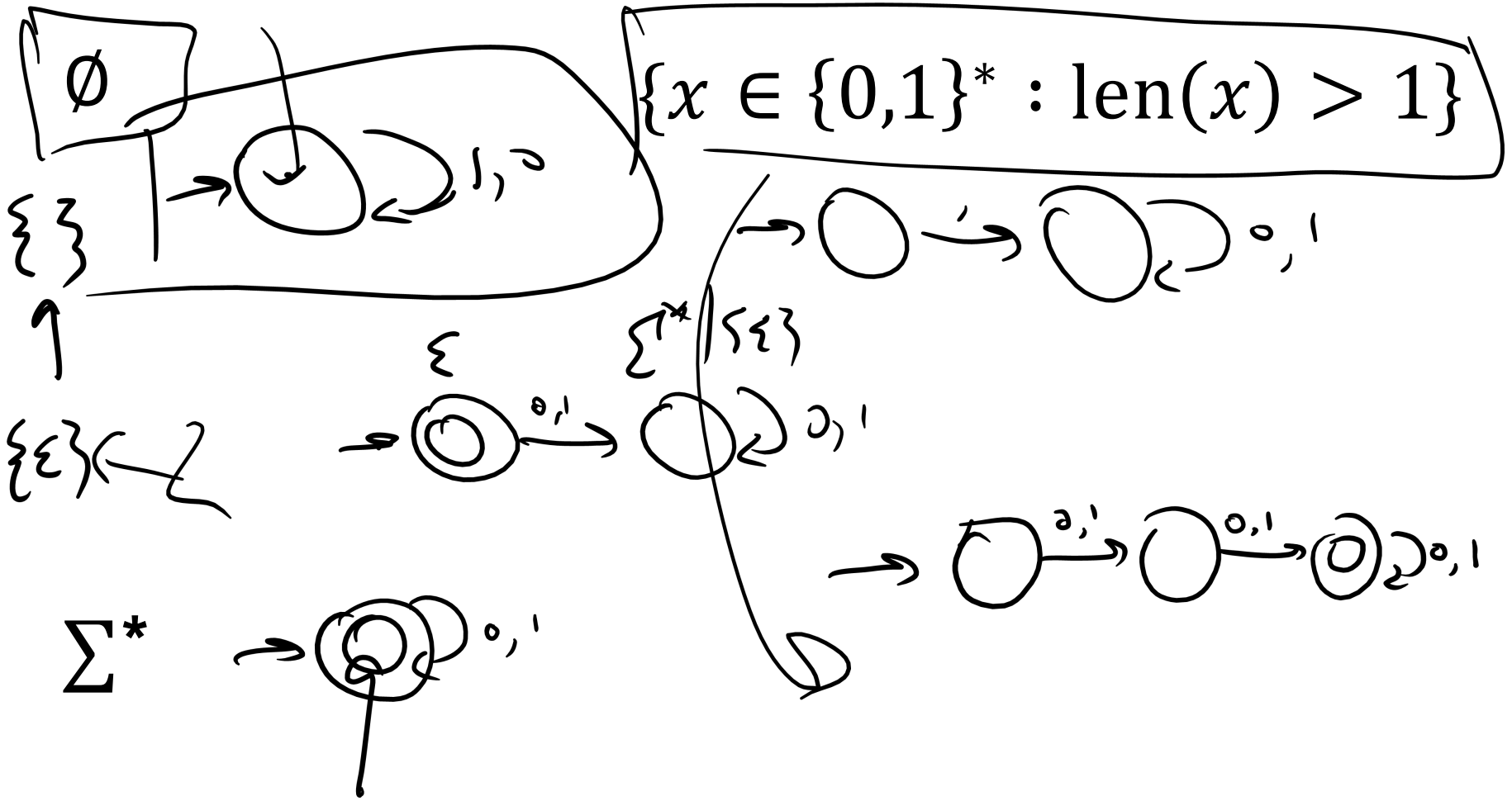
DFAs must have a transition for every character at every state!

Why is this not a DFA? Fix it!



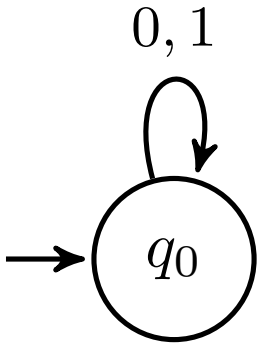
"Garbage states" are a useful concept. Whenever we KNOW we can't accept the string, just send it to a state that will always go back to itself. This is the way of saying "return false" in DFA-land.

For each of the following languages, create a DFA

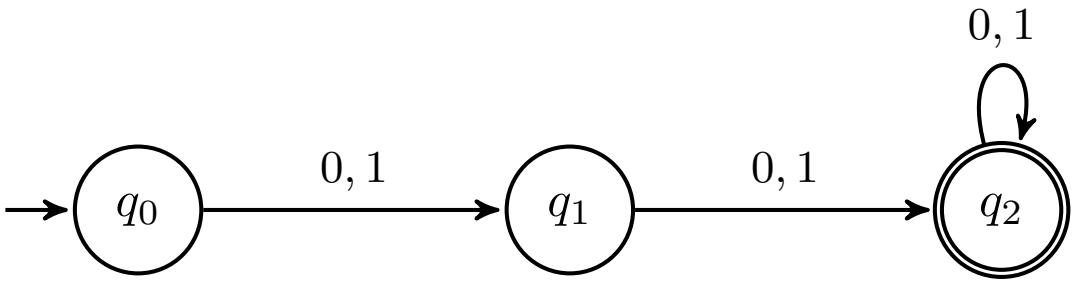


For each of the following languages, create a DFA

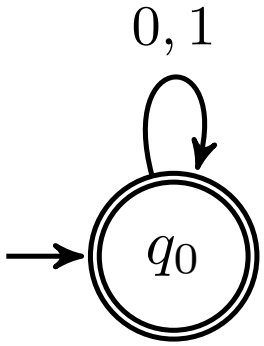
$\emptyset$



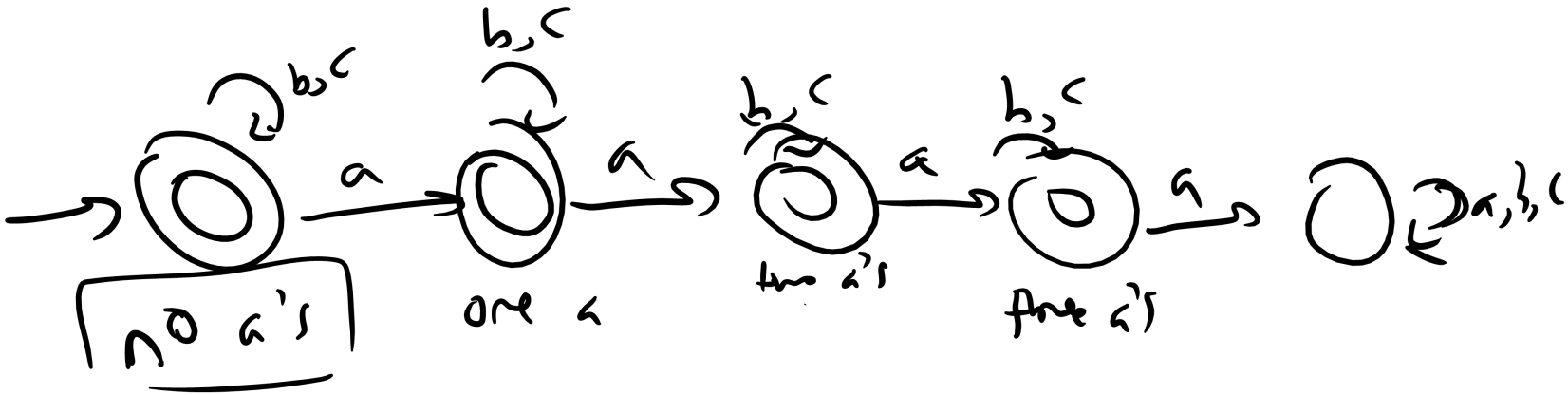
$\{x \in \{0,1\}^* : \text{len}(x) > 1\}$



$\sum^*$



FSM that accepts strings of a's, b's, c's with no more than 3 a's



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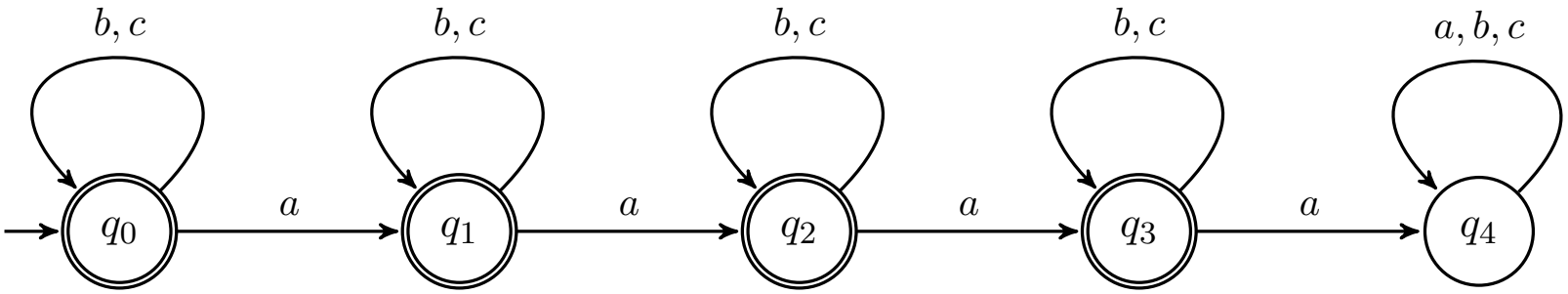
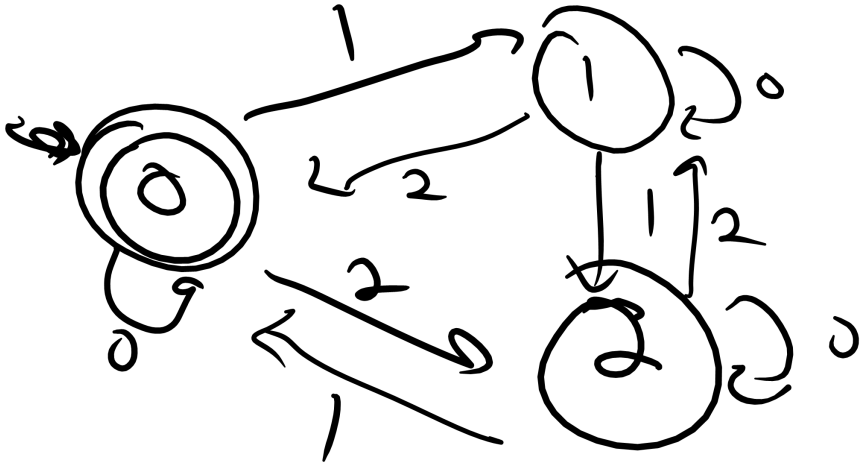


Strings over {0, 1, 2}*

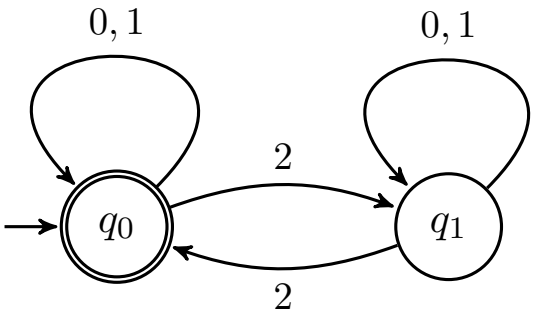
M_1: Strings with an even number of 2's

M_2: Strings where the sum of digits mod 3 is 0



Strings over {0, 1, 2}*

M_1: Strings with an even number of 2's



M_2: Strings where the sum of digits mod 3 is 0