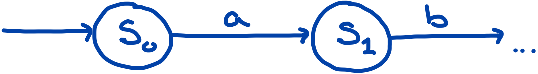
CSC 404 - Foundations of Computation

Section 1.3 – Nondeterministic Finite Automaton with Epsilon Transitions (ε-NFA)

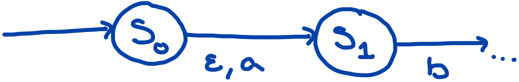
Nondeterministic Finite Automaton with Epsilon Transitions (ε-NFA)

Remark 1.3.1.

In the following NFA's we will make use of transition diagrams with ε allowed as a label. Think of each ε along a path as 'invisible' – that is, it contributes nothing to the string along the path. With this we are able to allow transitions on an empty input, i.e., no symbol at all.



Begins with ab...



Begins with ab OR b

Nondeterministic Finite Automaton with Epsilon Transitions (ε-NFA)

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In the following NFA's we will make use of transition diagrams with ε allowed as a label. Think of each ε along a path as 'invisible' – that is, it contributes nothing to the string along the path. With this we are able to allow transitions on an empty input, i.e., no symbol at all.

Example 1.3.2.

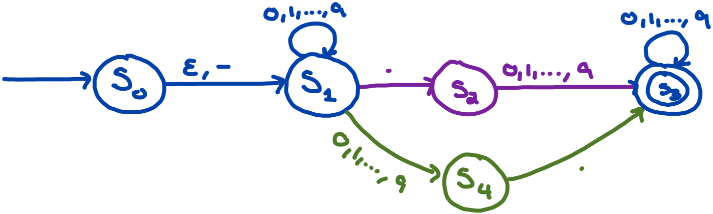
Consider designing an ε-NFA that accepts decimal numbers consisting of:

1. An optional $-$ sign,
2. A string of digits,
3. A decimal point, and
4. Another string of digits. Either this string of digits, or the string in 2. can be empty, but at least one of the two strings of digits must be nonempty

E.g. -13.37 { 867.5309 { -4.2 } .2 { 4.

Accepting Decimal Numbers: ε-NFA

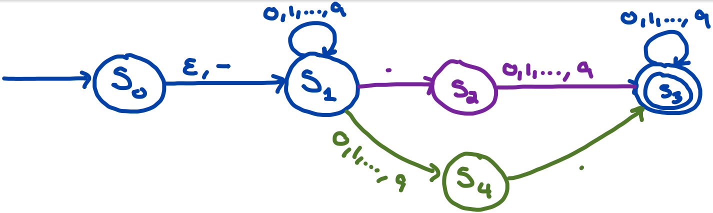
Accepting Decimal Numbers: ε-NFA

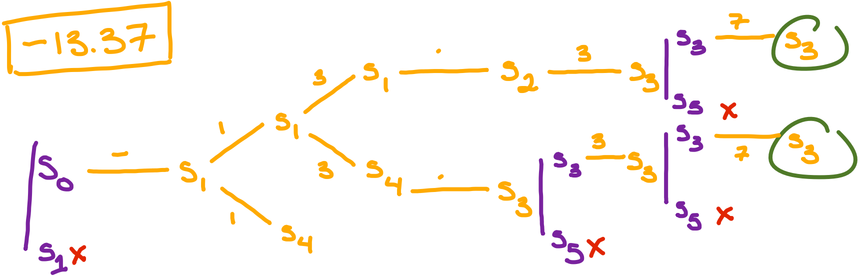


* At least 1 digit after the .

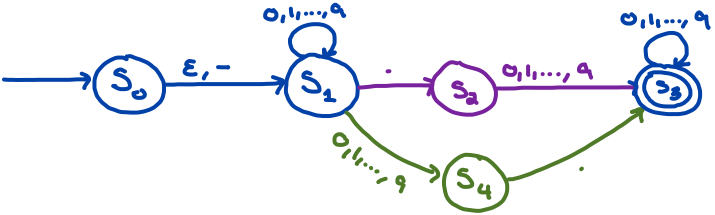
* At least 1 digit before the .

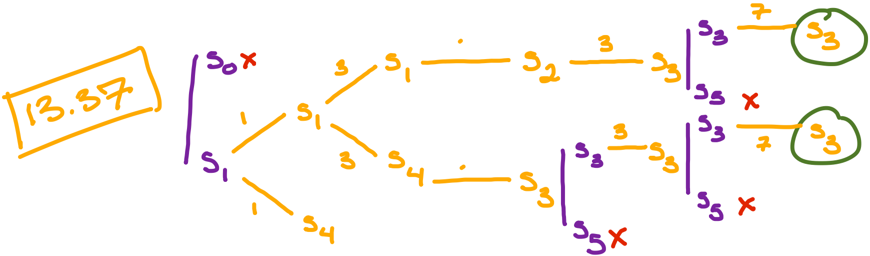
Accepting Decimal Numbers: ε-NFA



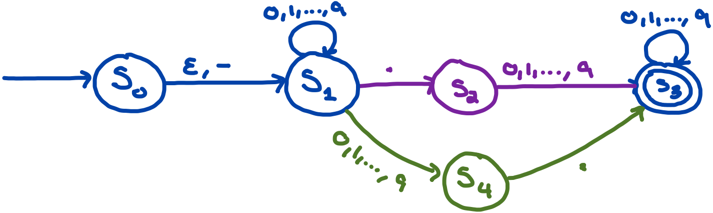


Accepting Decimal Numbers: ε-NFA

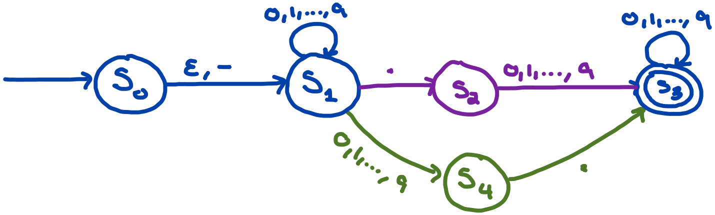




Accepting Decimal Numbers: ε-NFA

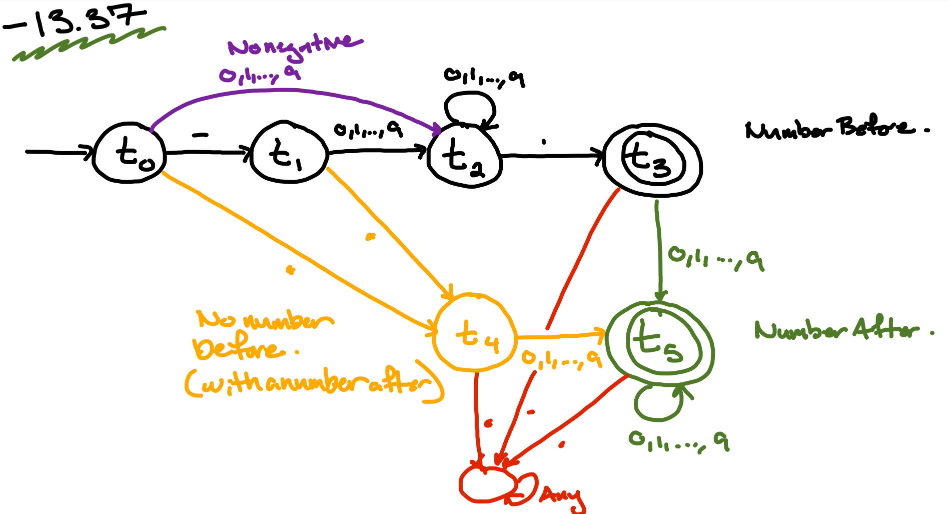


Accepting Decimal Numbers: ε-NFA



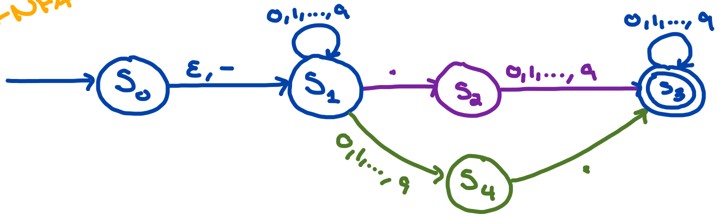
Accepting Decimal Numbers: ε-NFA

Accepting Decimal Numbers: DFA

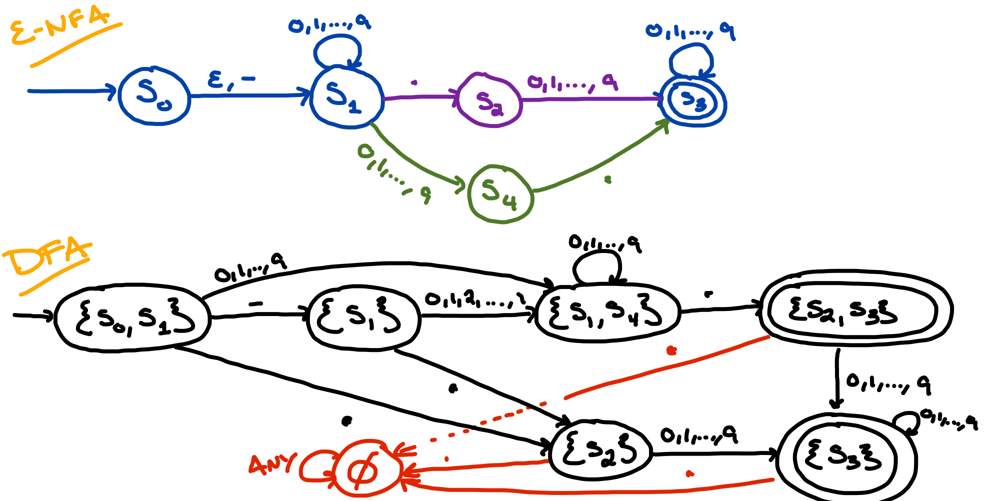


Accepting Decimal Numbers: DFA

ε-NFA

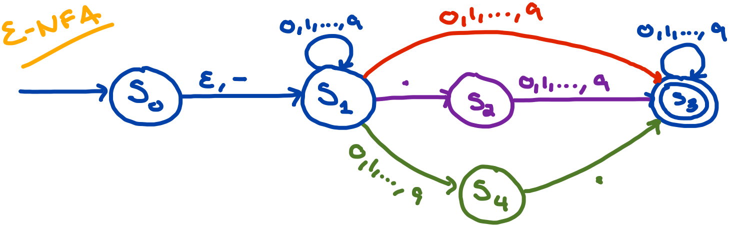


Accepting Decimal Numbers: DFA



Accepting Decimal Numbers: DFA

ε-NFA

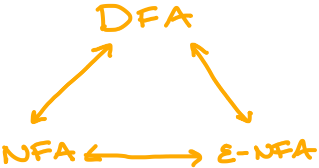


* Allows for no decimal point! (e.g. 42 accepted)

ε-NFA and DFA

Theorem 1.3.3.

A language L is recognized by some ε-NFA if and only if L is recognized by some DFA.



ε-NFA and DFA

Example 1.3.4.

Consider the set of all bit strings that contain an even number of 0s or contain exactly two 1s.

ε-NFA and DFA

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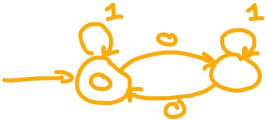
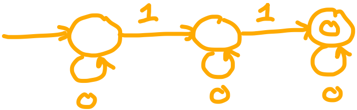
"HELPER MACHINES"



EVEN # OF ZEROS



EXACTLY TWO ONES

ε-NFA and DFA

Example 1.3.4.

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ε-NFA and DFA

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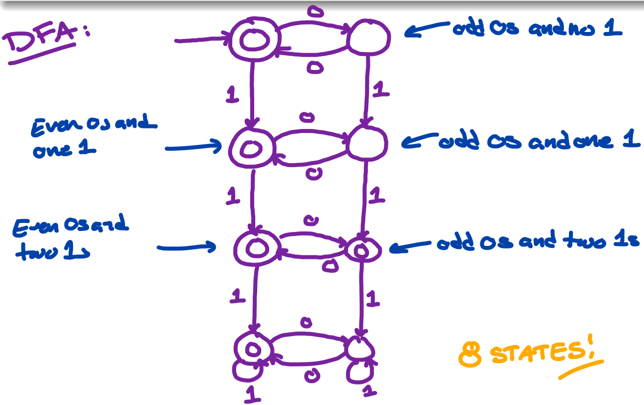
DFA:



8 STATES!

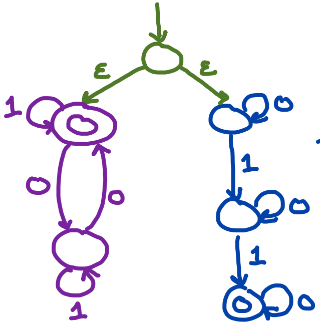
ε-NFA and DFA

Example 1.3.4.

Consider the set of all bit strings that contain an even number of 0s or contain exactly two 1s.

ε-NFA:

EVEN NUMBER OF ZEROS



EXACTLY TWO 1s

6 STATES!

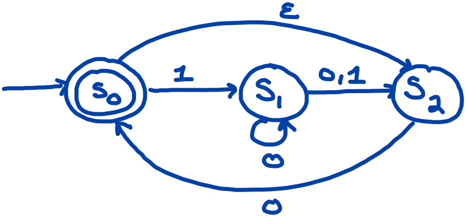
ε-NFA and DFA

Example 1.3.4.

Consider the set of all bit strings that contain an even number of 0s or contain exactly two 1s.

Example 1.3.5.

Consider the following Nondeterministic Finite Automaton with ε-transition (ε-NFA)



ε-NFA and DFA

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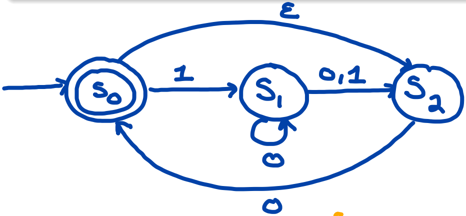
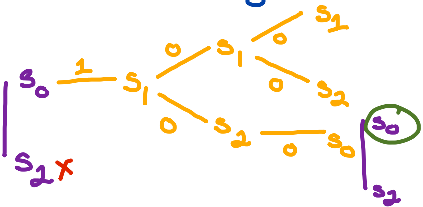


100



ACCEPT 100

ε-NFA and DFA

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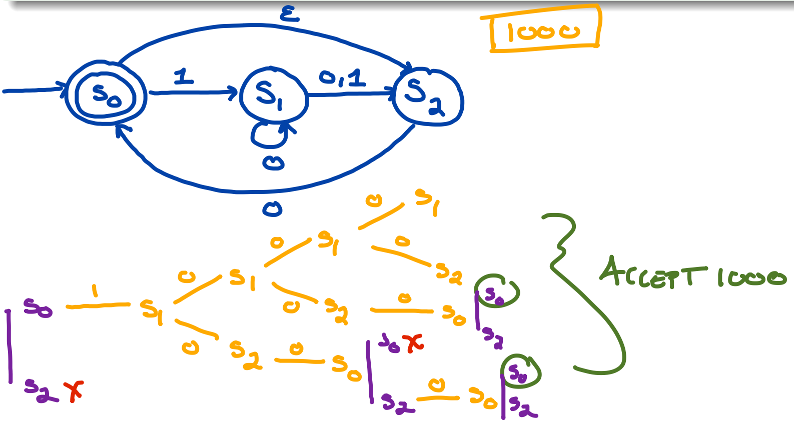

1000

ACCEPT 1000

ε-NFA and DFA

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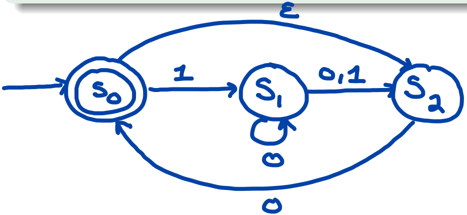
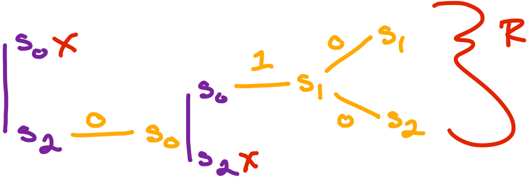


$\boxed{010}$



REJECT 010

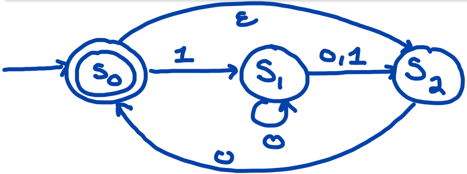
ε-NFA and DFA

Example 1.3.5.

Consider the following Nondeterministic Finite Automaton with ε-transition (ε-NFA)

Example 1.3.6.

Find a DFA that recognizes the same language as the following ε-NFA.



ε-NFA and DFA

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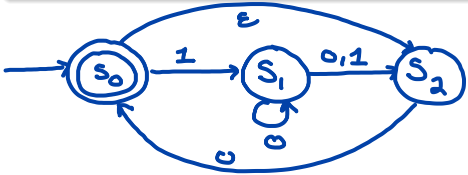

ε-NFA and DFA

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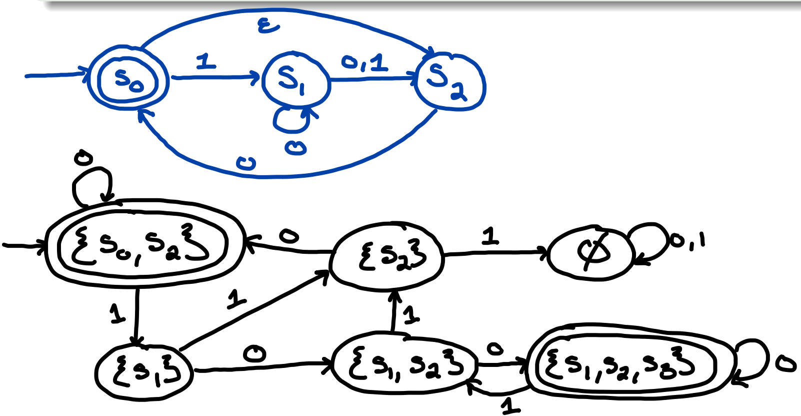

ε-NFA and DFA

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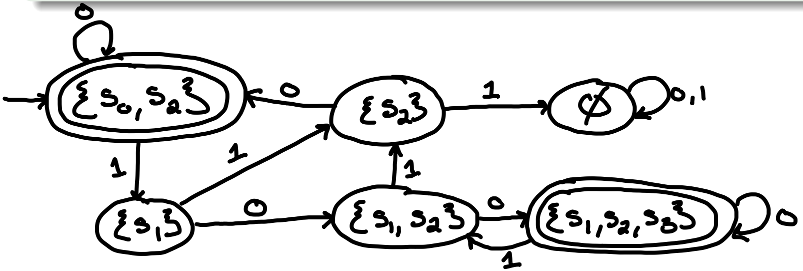

LANGUAGE? (More about this later :))

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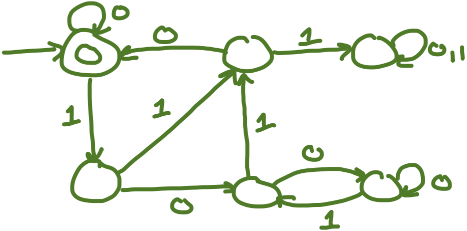

LANGUAGE? (More about this later ☺)