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Non-Deterministic Finite automata (NFA) and equivalence with DFA

Chapter - 2: Regular languages and finite automata

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Introduction

Finite Automata (FA) are computational models for recognizing regular languages

There are two types:

- Deterministic Finite Automata (DFA)
- Non-Deterministic Finite Automata (NFA)

In this section, we focus on:

- Defining NFAs
- Comparing NFAs with DFAs
- Proving equivalence through conversion

What is NFA?

- An NFA allows:
  - Multiple transitions for the same input symbol
  - Epsilon (ε) transitions (optional for ε-NFA)

- Accepts input if any path leads to an accepting state
- Think of it as "multiple possibilities" at each step

Formal Definition of NFA

An NFA is a 5-tuple:

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

Where:

- Q: Finite set of states
- Σ: Input alphabet
- δ: Transition function ($\delta: Q \times \Sigma \rightarrow 2^Q$)
- q_o: Initial state ($q_o \in Q$)
- F: Set of accepting/final states ($F \subseteq Q$)

Example NFA

NFA with ∑ = {0, 1} accepts all strings with 01.

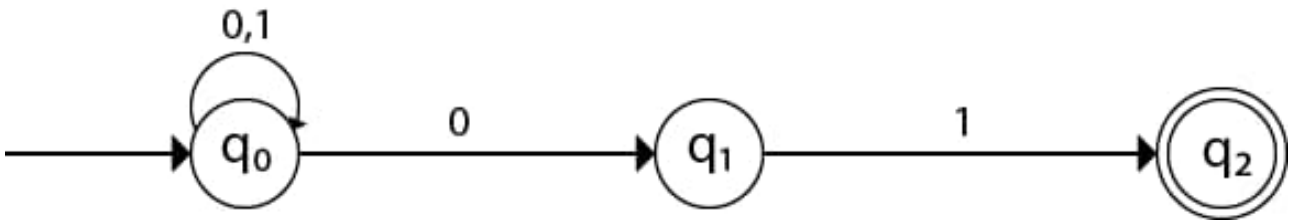
Fig: NFA

Present State	Next state for Input 0	Next State of Input 1
→q0	q1	ε
q1	ε	q2
*q2	q2	q2

Example NFA

Design an NFA with ∑ = {0, 1} accepts all string ending with 01.

Anything either 0 or 1	0	1



DFA vs NFA – Key Differences

Feature	DFA	NFA
Transition Func	δ: Q × Σ → Q	δ: Q × Σ → 2^Q
Determinism	Exactly one path	Multiple/zero paths allowed
Epsilon Moves	❌ Not allowed	✅ Allowed (in ε-NFA)
Design	Harder for complex languages	Easier to design
Execution	Easier to implement	Needs conversion before execution

NFA to DFA

There are four basic steps for the conversion of NFA to DFA.

Step 01: Draw an NFA Graph or diagram if it is not given.

Step 02: Draw the NFA transition Table.

Step 03: Convert the NFA transition Table to the DFA transition Table.

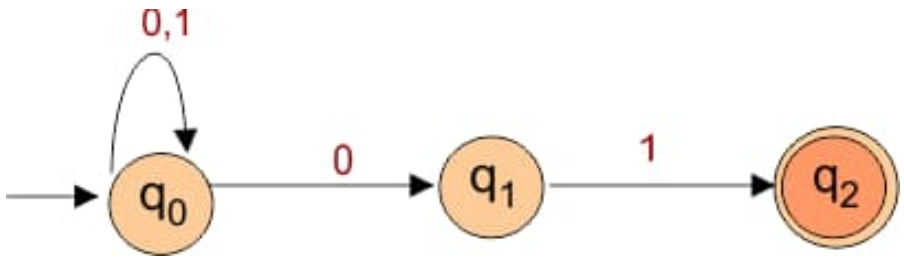
If any new state appears while converting the NFA to DFA then it will be added to the state column of the DFA Table.

If “x” was the final state in NFA, then all those states will be the final in DFA where “x” exists.

Step 04: Convert the DFA table to the DFA Diagram.

NFA to DFA – Example

Step 01: Draw NFA Graph
The following is the NFA graph that needs to be converted to a DFA.



Step 02: Draw the NFA transition Table.
The following is the NFA transition table which is derived from the given NFA.

States	0	1
→ q0	q0q1	q0
q1	ϕ	q2
*q2	ϕ	ϕ

NFA Transition Table

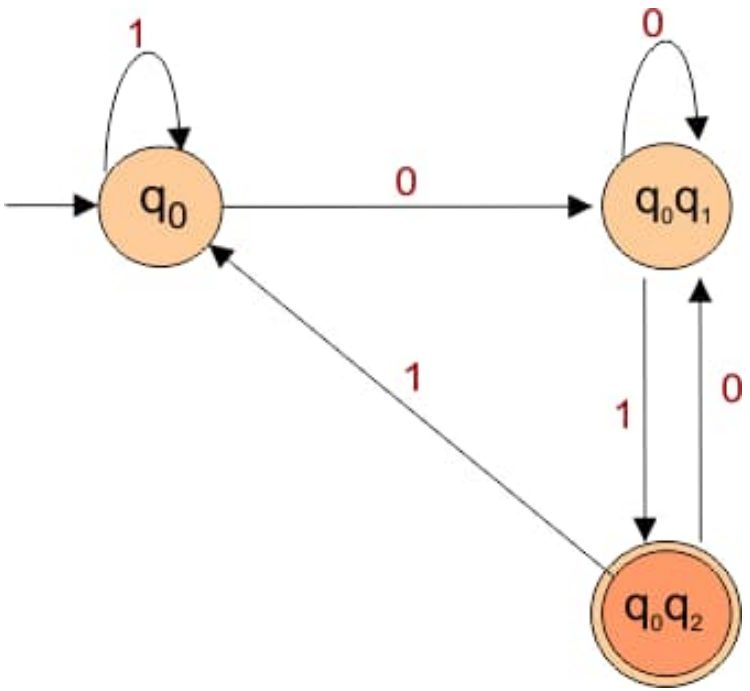
NFA to DFA – Example

Step 03: Conversion of NFA To DFA transition Table

States	0	1
→ q0	q0q1	q0
q0q1	q0q1	q0q2
*q0q2	q0q1	q0

DFA Transition Table

Step 4: Now draw DFA according to the DFA transition table



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