

Non-Deterministic Finite Automata Simulation Exercise in JFLAP

Abstract

JFLAP (Java Formal Languages and Automata Package) is an educational software tool designed to aid in the teaching and learning of theoretical computer science concepts, particularly formal languages, automata theory, and computational theory. JFLAP provides an interactive environment where users can design, simulate, and experiment with various formal models, including finite automata, pushdown automata, Turing machines, regular expressions, and grammars.

The tool supports step-by-step simulations, multiple input string testing, and visualizations of transitions, making it ideal for understanding abstract theoretical concepts in a concrete, visual manner. JFLAP also facilitates the construction and debugging of automata, allowing users to trace computation paths and identify errors in their designs.

Widely adopted in academic settings, JFLAP bridges the gap between theory and practical application, offering students an engaging platform to explore the foundational concepts of computation. By providing hands-on experience, JFLAP enhances understanding, promotes experimentation, and serves as an invaluable resource for both instructors and students in the field of computer science.

Problem Statement

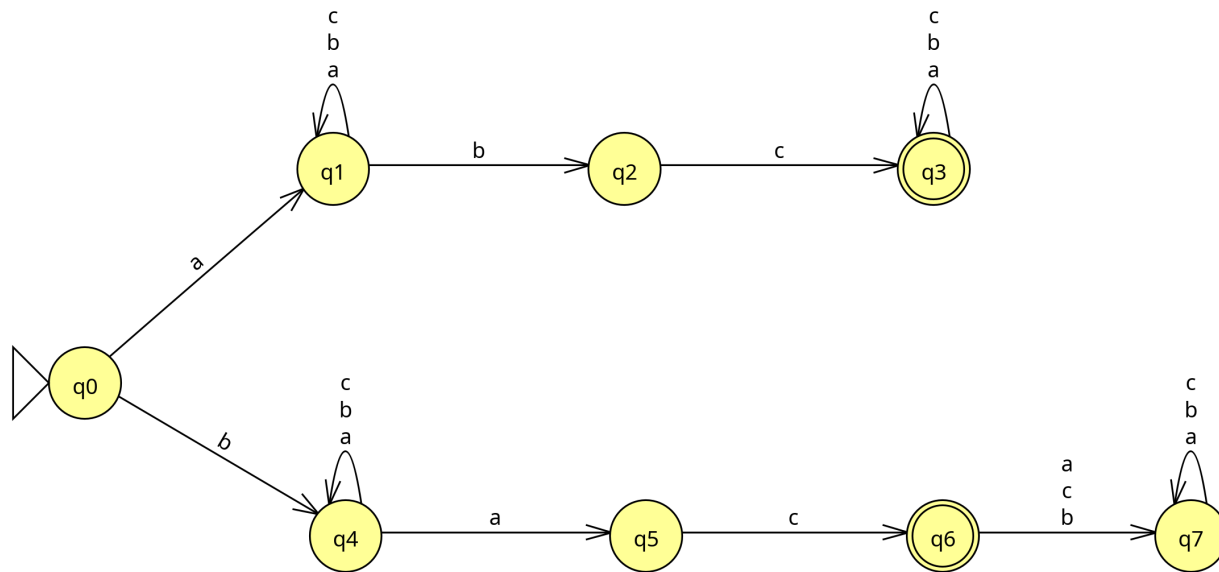
Construct a Non-deterministic Finite Automaton (NFA) for the language (L) over the alphabet ($\{a, b, c\}$) where a string (w) belongs to (L) if it satisfies the following conditions:

1. The string starts with an (a) and contains bc as a substring.
2. The string starts with a (b) and ends with ac.

Design Steps

- **Step 1:** Initial state q_0 with transition a to q_1 (to start the string with a).
- **Step 2:** From q_1 , create transitions for all symbols to stay in q_1 .
- **Step 3:** From q_1 , add b transition to q_2 .
- **Step 4:** From q_2 , add c transition to accepting state q_3 .
- **Step 5:** From q_3 , add all symbol transitions to stay in q_3 .
- **Step 6:** From q_0 , add b transition to q_4 .
- **Step 7:** From q_4 , add all symbol transitions to stay in q_4 .
- **Step 8:** From q_4 , add a transition to q_5 .
- **Step 9:** From q_5 , add c transition to accepting state q_6 .
- **Step 10:** From q_6 , add all symbol transitions to move to non-accepting state q_7 , so that symbols after encountering ac are not accepted.
- **Step 11:** From q_7 , add all symbol transitions moving to itself.

The final Non-Deterministic Finite Automata constructed is as follows:



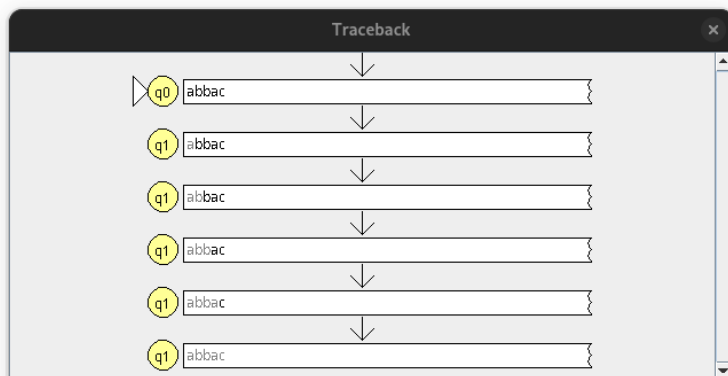
Tracing Strings

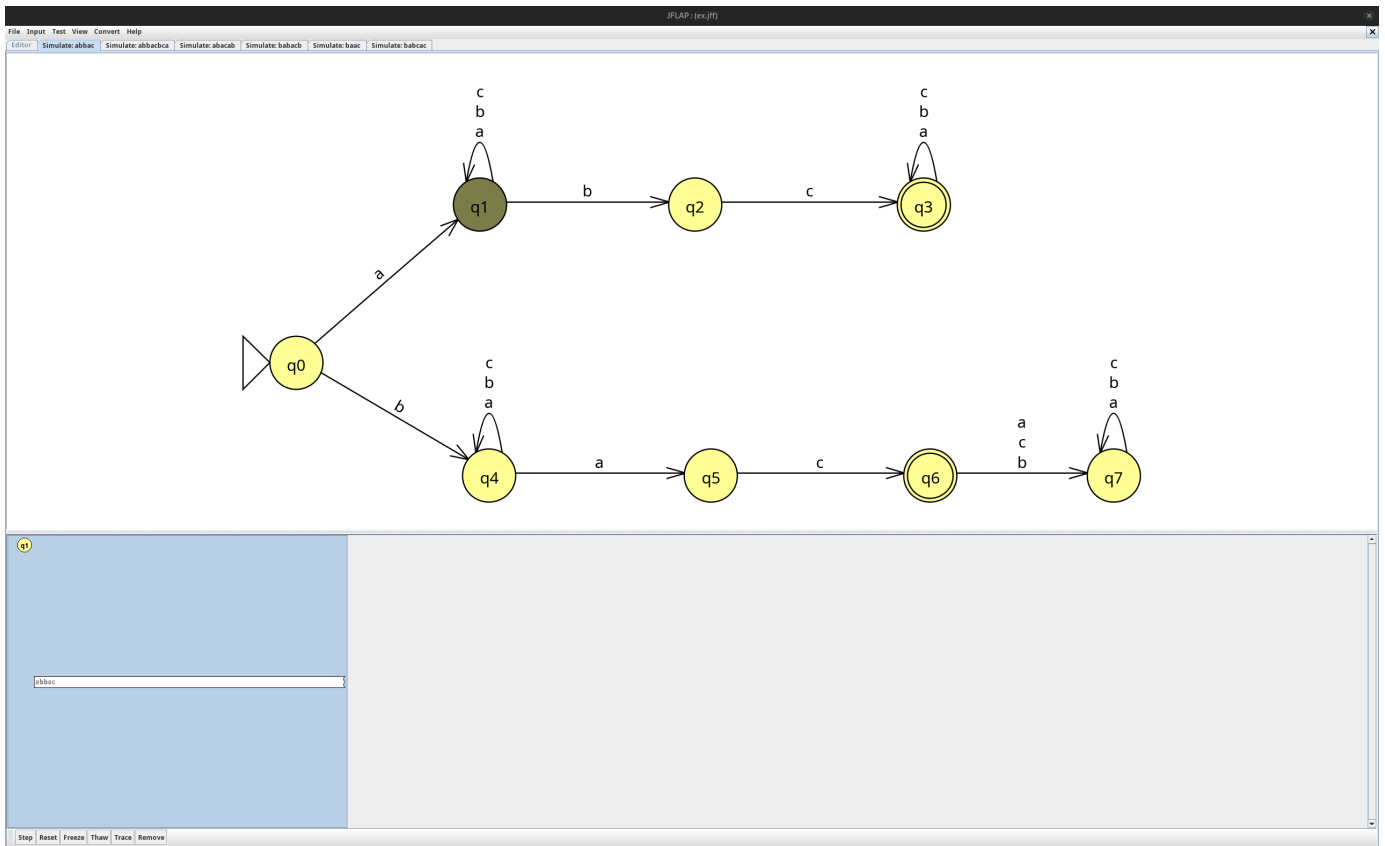
- **String 1: abbac**

1. The machine transitions from q_0 to q_1 on reading a.
2. Then, the machine transitions from q_1 to itself on reading b.
3. Then, the machine transitions from q_1 to itself on reading b.
4. Then, the machine transitions from q_1 to itself on reading a.
5. Then, the machine transitions from q_1 to itself on reading c.

Since q_1 is a non-accepting state, the string **abbac** is invalid.

Corresponding JFLAP Traceback



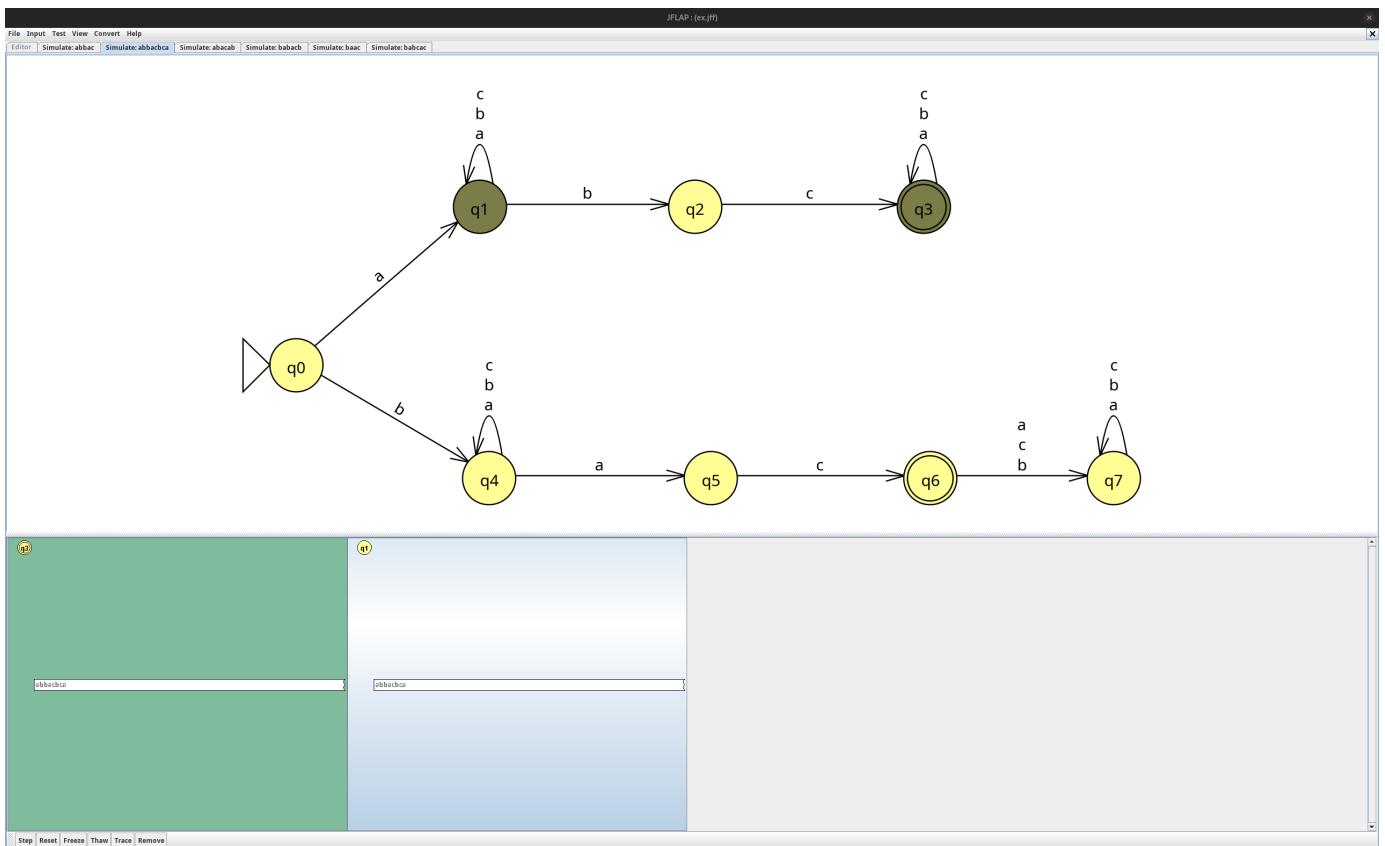
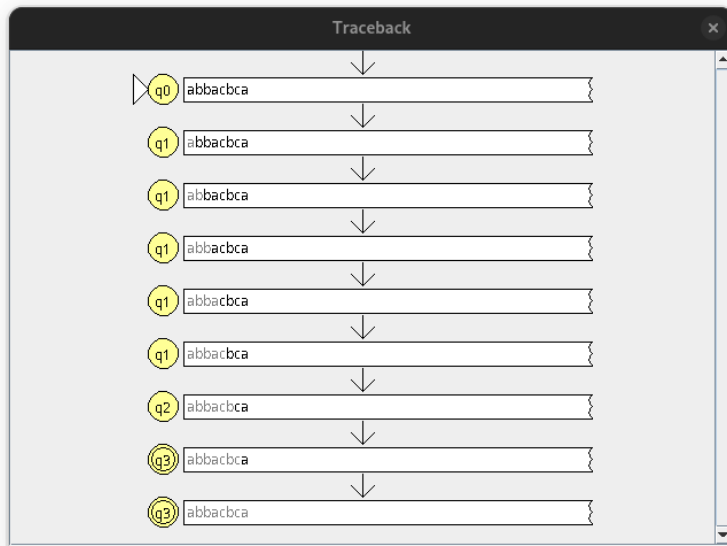


- **String 2: abbaabca**

1. The machine transitions from q_0 to q_1 on reading a.
2. Then, the machine transitions from q_1 to itself on reading b.
3. Then, the machine transitions from q_1 to itself on reading b.
4. Then, the machine transitions from q_1 to itself on reading a.
5. Then, the machine transitions from q_1 to itself on reading c.
6. Then, the machine transitions from q_1 to q_2 on reading b.
7. Then, the machine transitions from q_2 to q_3 on reading c.
8. Then, the machine transitions from q_3 to itself on reading a.

Since q_3 is an accepting state, the string **abbaabca** is valid.

Corresponding JFLAP Traceback

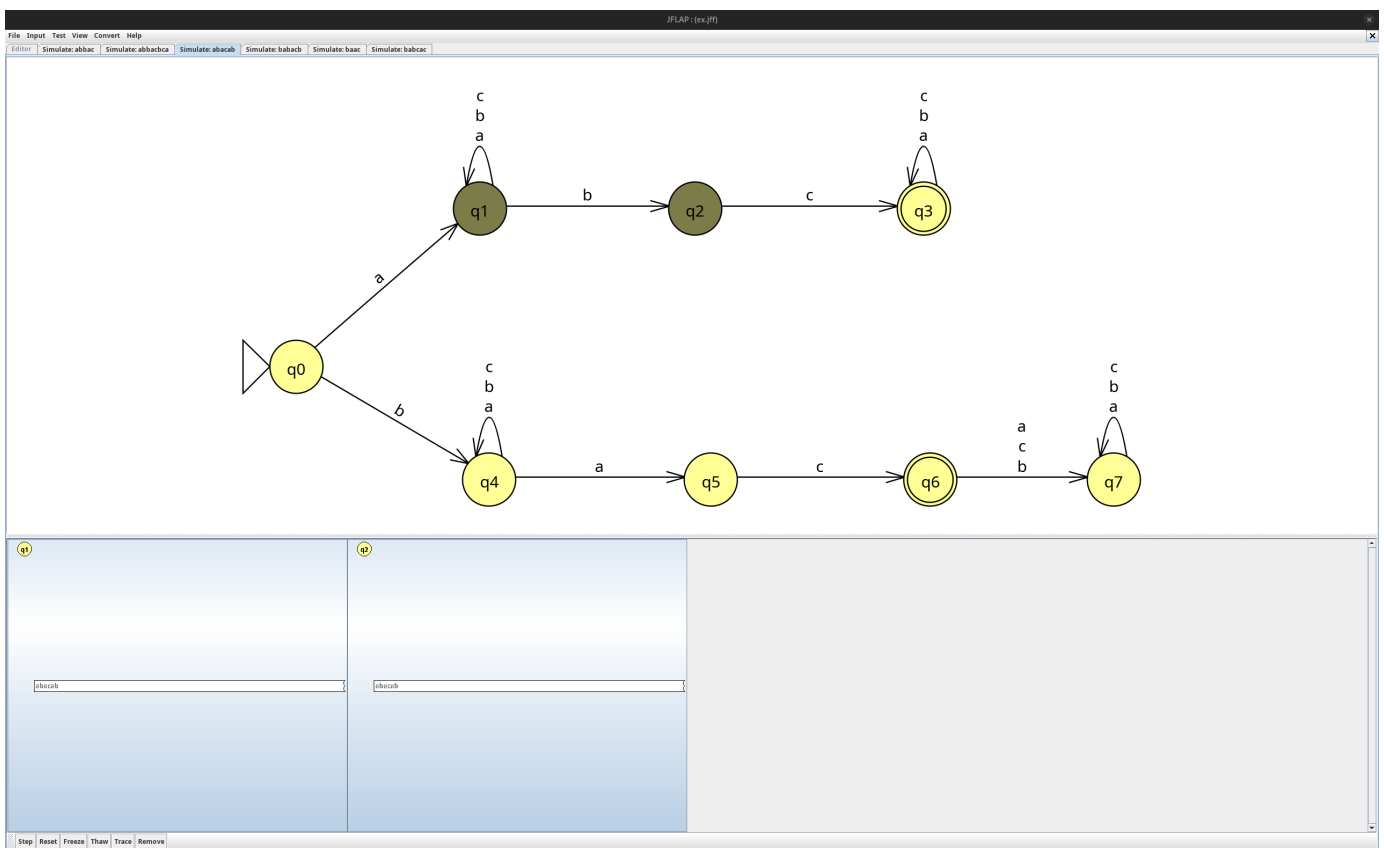
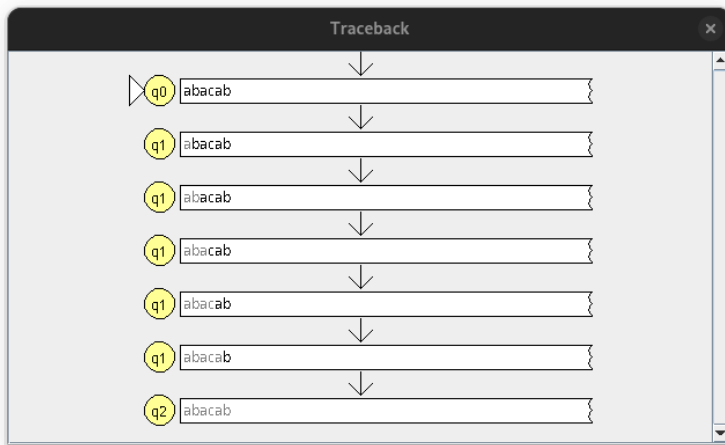


• String 3: abacab

1. The machine transitions from q_0 to q_1 on reading a.
2. Then, the machine transitions from q_1 to itself on reading b.
3. Then, the machine transitions from q_1 to itself on reading a.
4. Then, the machine transitions from q_1 to itself on reading c.
5. Then, the machine transitions from q_1 to itself on reading a.
6. Then, the machine transitions from q_1 to q_2 on reading b.

Since q_2 is a non-accepting state, the string **abacab** is invalid.

Corresponding JFLAP Traceback

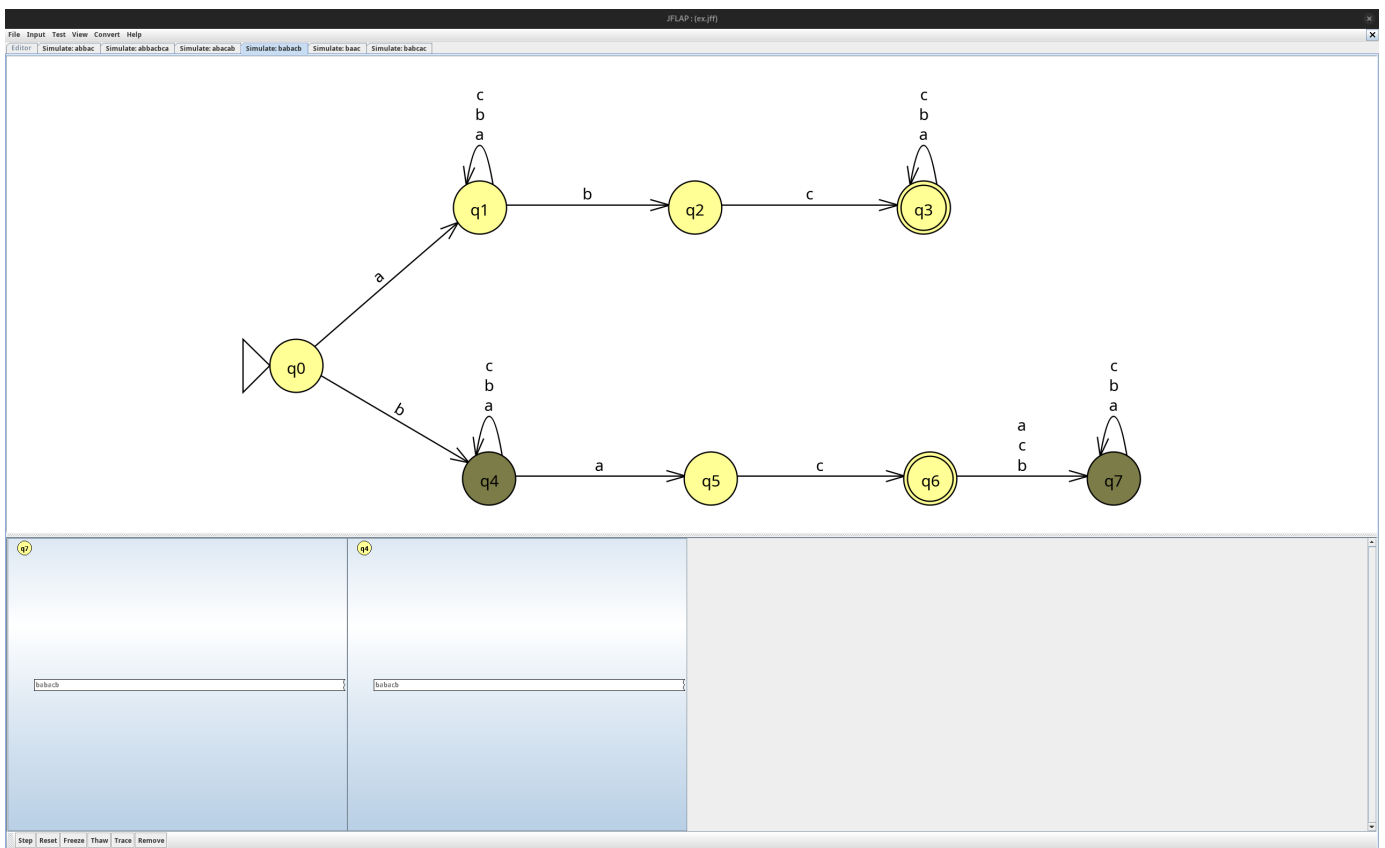
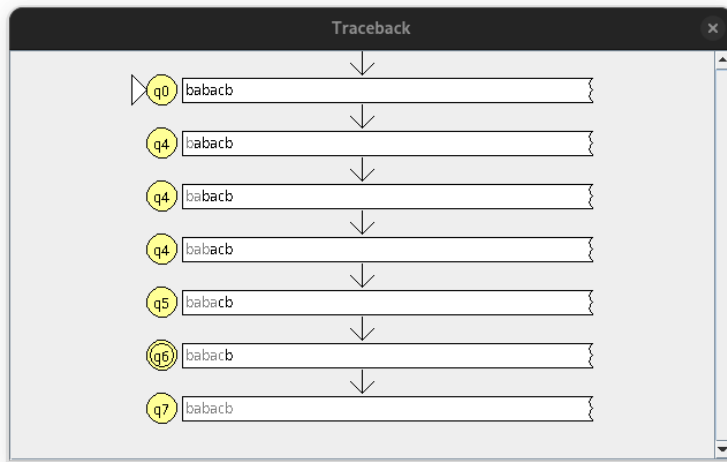


• String 4: babacab

1. The machine transitions from q_0 to q_4 on reading b.
2. Then, the machine transitions from q_4 to itself on reading a.
3. Then, the machine transitions from q_4 to itself on reading b.
4. Then, the machine transitions from q_4 to q_5 on reading a.
5. Then, the machine transitions from q_5 to q_6 on reading c.
6. Then, the machine transitions from q_6 to q_7 on reading b.

Since q_7 is a non-accepting state, the string **babacab** is invalid.

Corresponding JFLAP Traceback

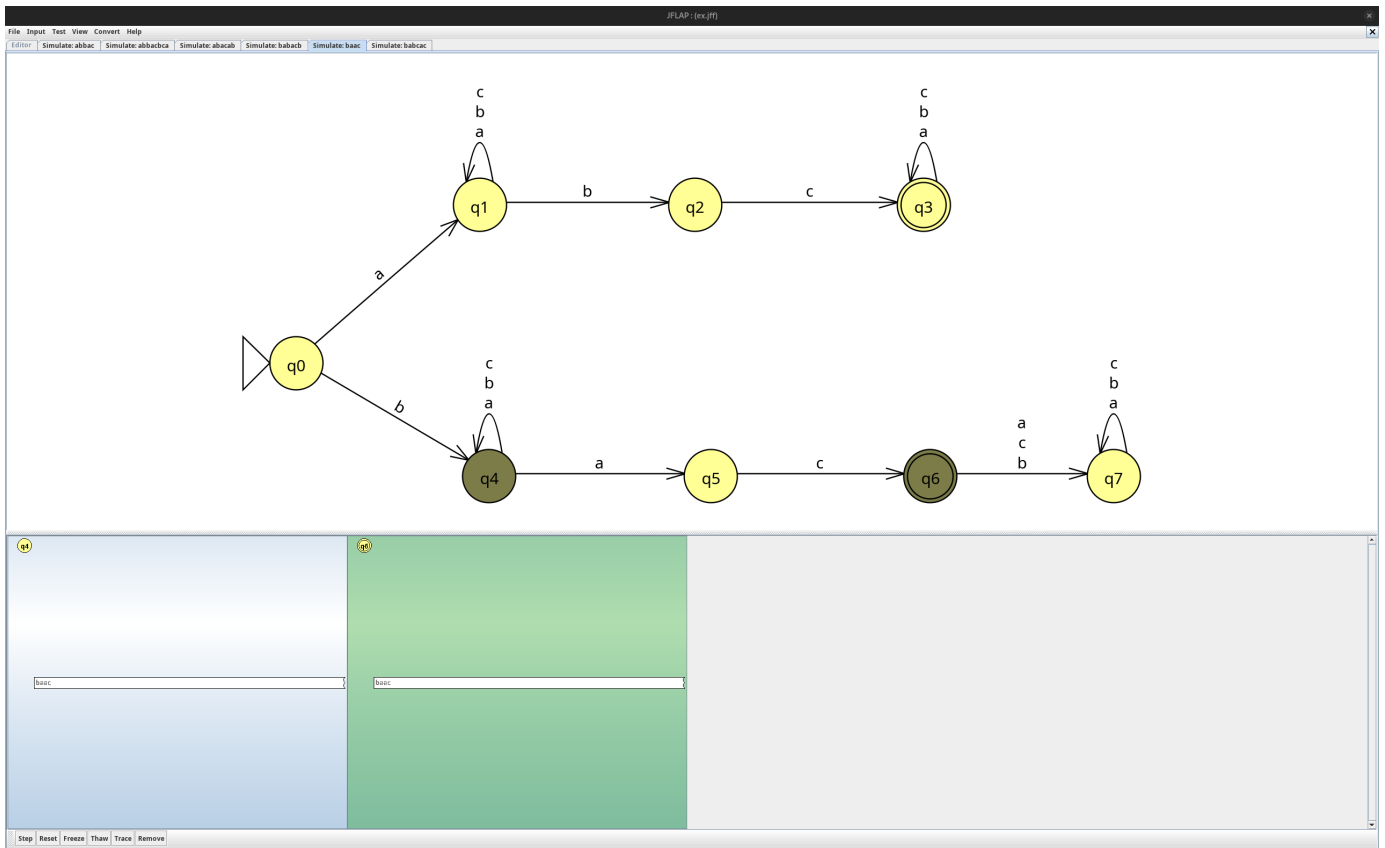
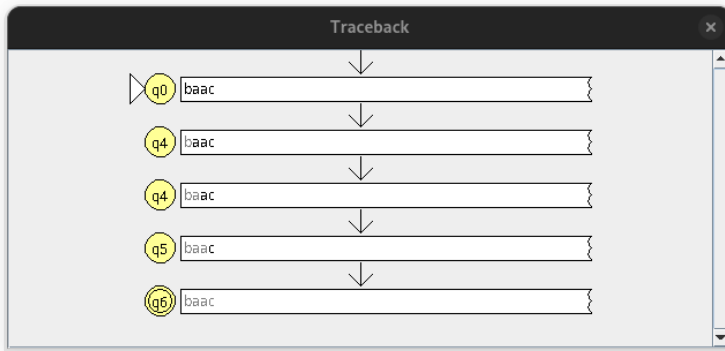


• **String 5: baac**

1. The machine transitions from q_0 to q_4 on reading **b**.
2. Then, the machine transitions from q_4 to itself on reading **a**.
3. Then, the machine transitions from q_4 to q_5 on reading **a**.
4. Then, the machine transitions from q_5 to q_6 on reading **c**.

Since q_6 is an accepting state, the string **baac** is valid.

Corresponding JFLAP Traceback

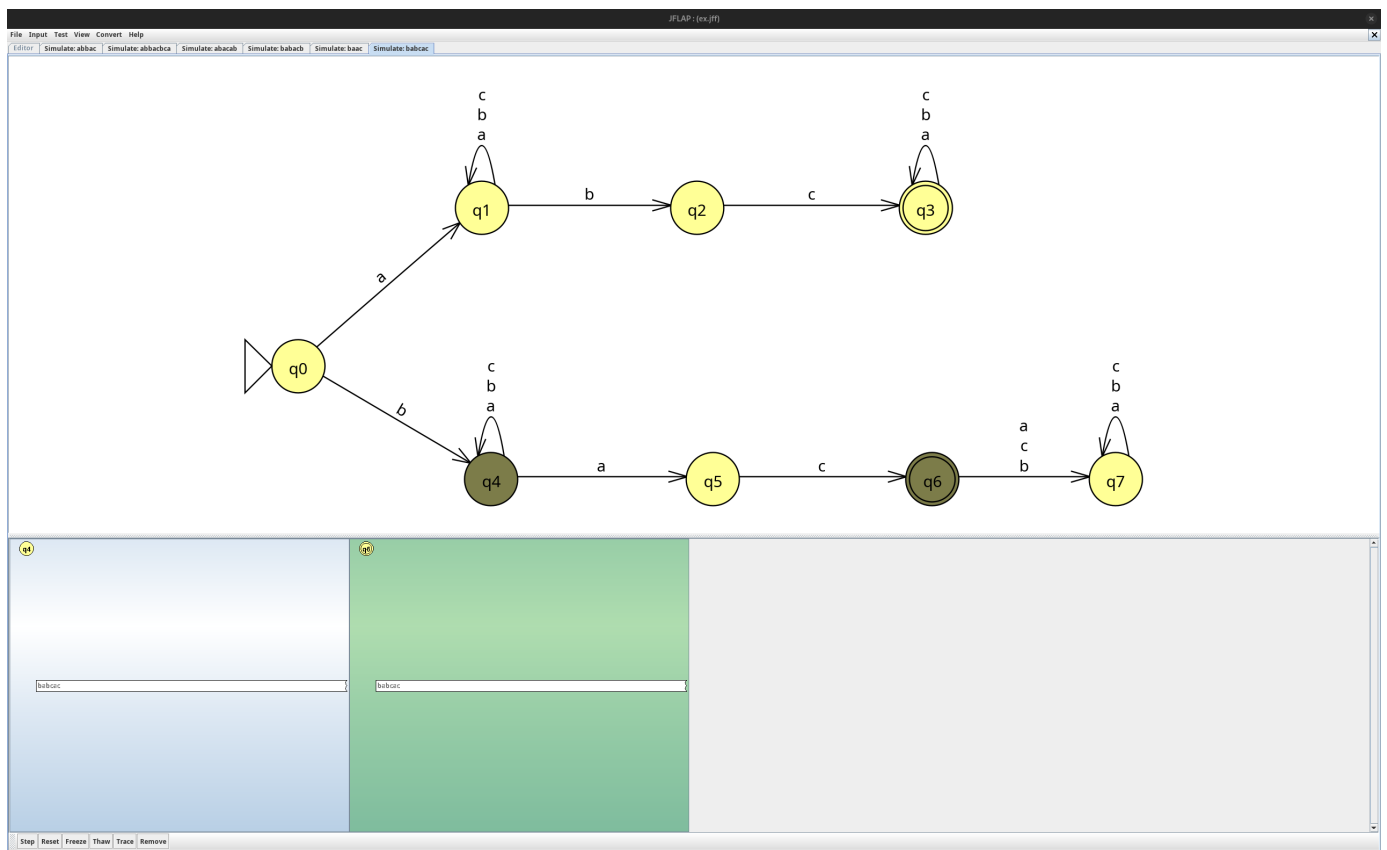
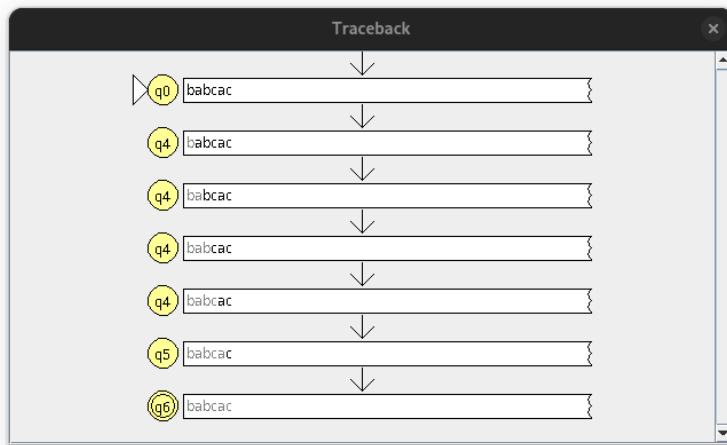


• String 6: babcac

1. The machine transitions from q_0 to q_4 on reading **b**.
2. Then, the machine transitions from q_4 to itself on reading **a**.
3. Then, the machine transitions from q_4 to itself on reading **b**.
4. Then, the machine transitions from q_4 to itself on reading **c**.
5. Then, the machine transitions from q_4 to q_5 on reading **a**.
6. Then, the machine transitions from q_5 to q_6 on reading **c**.

Since q_6 is an accepting state, the string **babcac** is valid.

Corresponding JFLAP Traceback



Multiple Run Output in JFLAP

The screenshot shows a software interface with a menu bar (File, Input, Test, View, Convert, Help) and a toolbar (Editor, Multiple Run). The main area displays an NFA diagram with states q_0 through q_7 . q_0 is the start state, and q_3 and q_6 are accepting states. Transitions are labeled with 'a', 'b', and 'c'. Self-loops on q_1, q_3, q_4, q_7 are labeled with 'c', 'b', 'a' in that order. The right panel, titled 'Table Text Size', shows a table with 'Input' and 'Result' columns. Below the table is a large empty text area and a toolbar with 'Load Inputs', 'Run Inputs', 'Clear', 'Enter Lambda', and 'View Trace'.

Input	Result
abbac	Reject
abbacbca	Accept
abacab	Reject
babacb	Reject
baac	Accept
babcac	Accept

The results of Multiple Run prove that the manual traces for all six strings under the previous heading are correct.

Five-Tuple Definition of the NFA

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

1. $Q = \{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7\}$
2. $\Sigma = \{a, b, c\}$
3. $\delta : Q \times \Sigma \rightarrow \mathcal{P}(Q)$ is the transition function defined by the following table:

State	a	b	c
q_0	$\{q_1\}$	$\{q_4\}$	\emptyset
q_1	$\{q_1\}$	$\{q_1, q_2\}$	$\{q_1\}$
q_2	\emptyset	\emptyset	$\{q_3\}$
q_3	$\{q_3\}$	$\{q_3\}$	$\{q_3\}$
q_4	$\{q_4, q_5\}$	$\{q_4\}$	$\{q_4\}$
q_5	\emptyset	\emptyset	$\{q_6\}$
q_6	$\{q_7\}$	$\{q_7\}$	$\{q_7\}$
q_7	$\{q_7\}$	$\{q_7\}$	$\{q_7\}$

4. q_0 is the initial state
5. $F = \{q_3, q_6\}$ is the set of accepting states

References

- <https://www.jflap.org>
- Introduction to Automata Theory, Languages and Computation, 3rd Edition, Pearson education, 2014

- <https://youtu.be/lRKE2RznkUU?feature=shared>
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Repository

All content referred to in this report have been pushed to the repository: <https://github.com/themohitnair/toc-jflap-exercise>

Conclusion

In this exercise, a Non-Deterministic Finite Automaton (NFA) was successfully constructed and simulated in JFLAP to recognize strings satisfying specific language constraints. Through careful design and step-by-step tracing of multiple test strings, we validated the correctness of the NFA. The simulation outputs confirmed the alignment of the NFA's behavior with the given language rules, demonstrating its ability to accurately distinguish valid strings from invalid ones.

The use of JFLAP proved invaluable in visualizing transitions and debugging the automaton, reinforcing its effectiveness as an educational tool for exploring theoretical concepts. By defining the NFA using its formal five-tuple representation and testing it through multiple-run simulations, clarity and rigor in the design process was ensured. This exercise highlights the importance of tools like JFLAP in bridging abstract computational theories with practical applications, enhancing both comprehension and learning outcomes.
