Design and Comparison of Mealy and Moore Machines for Coffee Vending System

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1. Introduction

Finite State Machines (FSM) are the fundamental models of computation used to design sequential logic systems and automation processes.
In this report, a coin-operated coffee vending machine is designed using two models of FSM the Mealy and the Moore machines and their
performances are compared. The machine accepts ₹5 and ₹10 coins. The cost of coffee is ₹15. When sufficient coins are inserted, the
machine dispenses coffee and, if necessary, returns ₹5 as change.

2. Theoretical Background

FSMs are abstract mathematical models that represent systems with a finite number of states. They transition between states based
on inputs and produce corresponding outputs.

• A Mealy machine is defined as $M = (Q, \Sigma, \Delta, \delta, \lambda, q_0)$, where:

- Q: Set of states
- Σ: Input alphabet
- Δ: Output alphabet
- δ: State transition function $Q \times \Sigma \rightarrow Q$
- λ: Output function $Q \times \Sigma \rightarrow \Delta$
- q_0: Initial state

Outputs in a Mealy machine depend on both the present state and the input.

• A Moore machine is defined as M = (Q, Σ, Δ, δ, λ, q_0), where:

- λ: Output function Q → Δ

Outputs depend only on the present state, not the input.

3. System Description

Inputs (Σ) = {5, 10} represent ₹5 and ₹10 coins inserted into the vending machine.
Outputs (Δ) = {(D, R5)} where D = 1 represents dispensing coffee and R5 = 1 represents returning ₹5 as change.

4. Mealy Machine Model

The Mealy machine has 3 states:
q_0 → ₹0 collected
q_5 → ₹5 collected
q_{10} → ₹10 collected

Transition and Output Table:

Current State	Input	Next State	Output (D, R5)
q_0	5	q_5	(0,0)
q_0	10	q_{10}	(0,0)
q_5	5	q_{10}	(0,0)
q_5	10	q_0	(1,0)
q_{10}	5	q_0	(1,0)
q_{10}	10	q_0	(1,1)

Explanation: Outputs are generated during transitions. For example, inserting ₹10 in state q_{10} produces (1,1), which means the
machine dispenses coffee and returns ₹5 as change.

5. Moore Machine Model

The Moore machine has 5 states:

$q_0 \rightarrow$ ₹0, $q_5 \rightarrow$ ₹5, $q_{10} \rightarrow$ ₹10, $q_{15} \rightarrow$ ₹15 (dispense), $q_{20} \rightarrow$ ₹20 (dispense + change)

Transition and Output Table:

Current State	Input	Next State	Output (D, R5)
q_0	5	q_5	(0,0)
q_0	10	q_{10}	(0,0)
q_5	5	q_{10}	(0,0)
q_5	10	q_{15}	(0,0)
q_{10}	5	q_{15}	(0,0)
q_{10}	10	q_{20}	(0,0)
q_{15}	-	q_0	(1,0)
q_{20}	-	q_0	(1,1)

Explanation: Outputs are associated with states q_{15} and q_{20}. The output (1,0) in q_{15} represents dispensing coffee,
and (1,1) in q_{20} represents dispensing coffee with a ₹5 return.

6. Comparison Between Mealy and Moore Machines

Feature	Mealy Machine	Moore Machine
Output depends on	Current state & input	Current state only
Reaction speed	Immediate	One cycle delayed
No. of states	Fewer (3)	More (5)
Output stability	May glitch if inputs bounce	Very stable
Implementation	Compact and efficient	Easier to debug
Suitable for	Real-time quick response	Reliable timing systems

7. Advantages, Disadvantages, and Use Cases

• Mealy Machine:
- Advantages: Fewer states, immediate response.
- Disadvantages: Sensitive to input glitches.
- Best for: Compact digital designs requiring quick outputs.

• Moore Machine:
- Advantages: Stable outputs, easy hardware implementation.
- Disadvantages: More states, one-cycle output delay.

- Best for: Safety-critical or synchronized systems.

8. Conclusion & Recommendation

Both Mealy and Moore machines are valid FSM representations for the coffee vending machine. The Mealy model requires fewer states
and reacts instantly to inputs, making it more efficient for compact digital circuits. The Moore machine offers more predictable,
stable outputs, making it safer for hardware prone to signal noise.

In theoretical contexts, both models should be demonstrated to highlight their distinctions. For real-world applications, a Mealy-based
design with input debouncing or a counter-based hybrid FSM is recommended for efficiency and responsiveness.

9. References

1. Theory of Automata and Computation – Hopcroft & Ullman
2. Lecture notes on Finite State Machines – University resources
3. Internal slides: TOA External Presentation (Coffee Vending Machine Design)