VENDING MACHINE

A Practical Application of Automata Theory Using C# WinForms

AUTHORS

MUHAMMAD SAJEEL (66095)

SAIFULLAH KHAN (66047)

Department of Computer Science

PAF KIET NORTH CAMPUS

Abstract:

This project presents an **Automata-Based Vending Machine System** implemented using **C# and Windows Forms**, demonstrating a real-world application of **Finite Automata (FA)** and **state transition functions**. The vending machine operates by acceping coins as input symbols, transitioning through predefined states, and dispensing products when a final accepting state (Q3) is reache. The system accurately models vending machine behavior using concepts such as **start states, intermediate states, accepting states, and transitions**, thereby bridging the gap between theoretical automata concepts and practical software development.

Keywords:
Automata Theory, Finite Automata, State Transition Diagram, Vending Machine, C#, WinForms, DFA, Software Modeling

Contents

Chapter 1: Introduction

1.1 Problem Domain

Modern vending machies are widely used automated system that require **accurate transaction handling, state management, and decision-making**. Designing such systems manually without formal modeling can lead to logical errors, incorrect poduct dispensing, or improper handling of invalid inputs. This project addresses the challenge of modeling a vending macine using **formal automata concepts**, ensuring correctness and predictability.

1.2 Project Significance

This project demonstrates how **finite automata theory** can be applied to simulate real-life systems. By implementing a vending machine using **states and transitions**, students gain practical exposre to abstract theoretical concepts. The project also serves as an eductional tool to understand **Deterministic Finite Automata (DFA)** in a visual and interactive manner using a **Windows orms GUI**.

1.3 Core Motivation

The motivation behind this projct is to transform abstract automata concepts into a **tangible and interactive application**. Vending machines are ideal xamples of state-based systems where user inputs directly influence system behavior. Implementing such a system in C# helpsbridge theory and real-wold software engineering

Chapter 2: Literature Review and Related Work

Finite automata have long been used to model control systems, transactiobased machines, and digital circuis. Hopcroft et al. describe automata as effective tools for modeling sequential logic and decision-making sysems. Several research works highlight vending machines as classic examples of DFA applications due to their deterministic nature.

Previous implementations of vending machines using automata have been develoed in simulation ools and hardware description languages.However, many lack user-friendly graphical interfaces or integration with modern programming environments. This project differentiates itself by implementing a GUI-based vending machine using C# WinForms, making automata conceps more accessible and interactive for learners.

Chapter 3: Methodology

The development of the Automata-Based Vending Machine Systemollowed a structure and ystematic methodology to ensure correctness and alignment with automata theory principles.

3.1 Research Phase:
An in-depth study of finite automata and deterministic finite atomata (DFA) was conducted, wit a focus on modeling vending machines as state-based systems where coin inputs act as symbols and product dispensing represents an acceptig state.

3.2 Design Phase:
State transition diagrams were designed to represent th vending machine behavior. The initial state represents zero balance, intermediate states represent accumulated amounts, and accepting state represent sufficient alance for purchasing a product

3.3 Development Phase:
The designed automata were implemented using C# an Windows Forms. Backen logic managed state updates, coin insertion, product selection, and system reset after dispensig, while the graphica interface visualized states and transitions.

3.4 Testing Phase:
The system was tested using various scenarios, including valid coin sequences,

3.5 Refinement Phase
Minor refinements were made to improve user experience and visual clarity of the automata transitions.

Chapter 4: System Architecture and Problem Definition

This chapter explains the overall architecture of the Automata-Based Vending Machine System and clearly defines the proble being addressed

4.1 Problem Statement

Traditional vending machine implementations often rely on ad-hoc logic, which can result in incorrect handling of coin inputs, invalid state transitions, or improper product dispensing.

The problem addressed in this project is to design and implement a vending machine that **correctlyandles coin insertion and product selectin** using a formal, structured, and error-free approach based on finite automata

4.2 System Objectives

The primary objectives of the Automata-Based Vending Machine System are as follows:

- To model the vendin machine using foral finite automata concepts, including states, transitions, input symbols, and accepting states.
- To ensure correct and deterministic state transitions based on user inputs such as coin insertion and product slection.
- To dispnse products only when the system reaches a valid acceptig state (Q3), representing sufficient balance for a selected product
- To prevent incorrect product dispensing by rejecting invalid input sequences and insufficient funds.
- To provide a simple, intuitive, and interactivegraphical user interface that allows users to understand and observe the automata behavior visually.

Chapter 5: Technology Stack

Programming Language: C#

Framework: .NET Framework

User Interface: Windows Forms (WinForms)

Core Logic: Deterministic Finite Automata (DFA)

Development Environment: Visual Studio

Chapter 6: Experimental Analysis and Results

To evaluate the corectness and reliability of the vending machine system, multiple test scenarios were performed under controlled conditions.

Invalid scenarios, such as insufficient coin insertion or incorrect product selection, were also tested. In these case, the system correctly prevented product dispensing and prompted the user to insert additional coins.

The system consistetly reset after each completed transaction, ensuring readiness for subsequent users. The experimental results confirmed that the automata-based design provides high accuracy, reliability, and predictable behavior, validating the effectiveness of using finite automata for vending machine modeling.

Chapter 7: Conclusion and Future Work

7.1 Conclusion

This project successfully demonstrates hw finite automata theory can be applied to a practical system. Using DFA esures correct handling of inputs and product dispensing. The project also serves as a helpful learning tool for understanding automata concepts.

7.2 Future Work

Possible future improvements include:

- Adding multiple products with different prices
- Extending the system using NFA concepts
- Connecting the system to a database
- Developing a web-based version

Reviewed Literature

1. Hopcroft, J. E., Motwani, R., & Ullman, J. D. (2019). *Introduction to Automata Theory, Languages, and Computation*. Pearson.

2. Lin, F., & Wonham, W. M. (1988). *On observability of discrete-event systems*. Information Sciences.

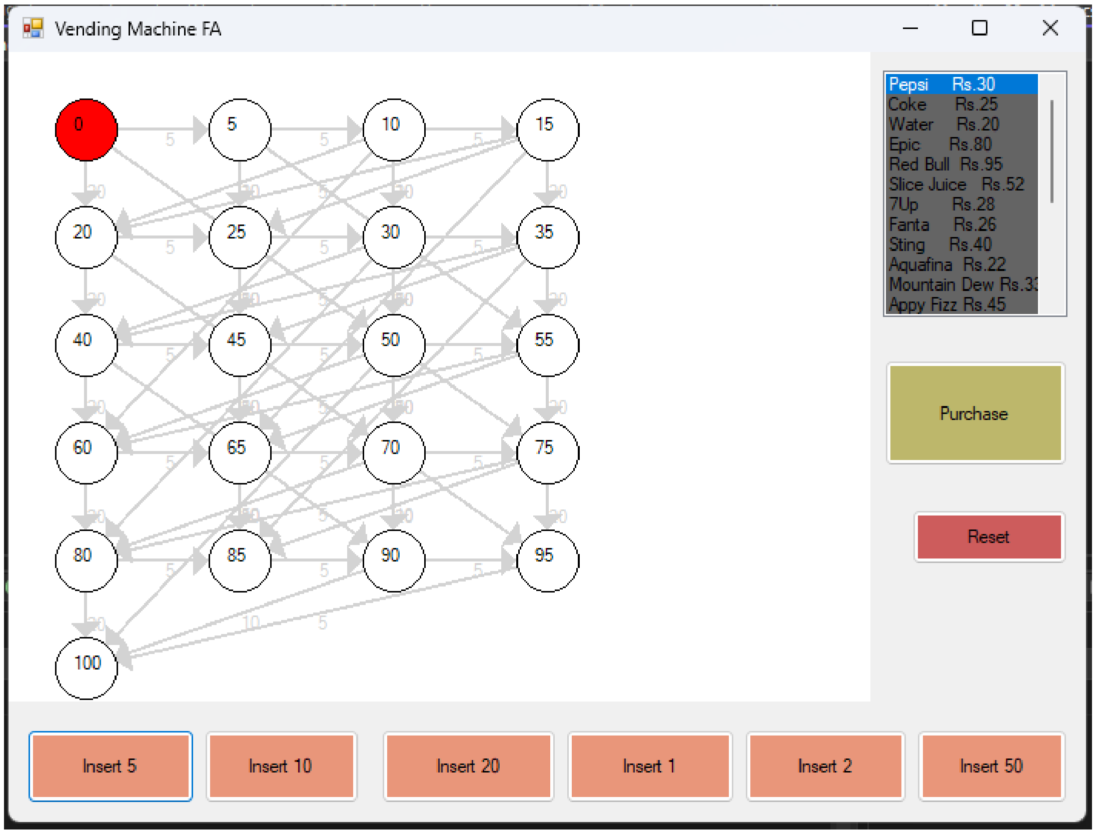
3. Microsoft Corporation. *Windows Forms Documentation*.

4. Sipser, M. (2012). *Introduction to the Theory of Computation*. Cengage Learning.

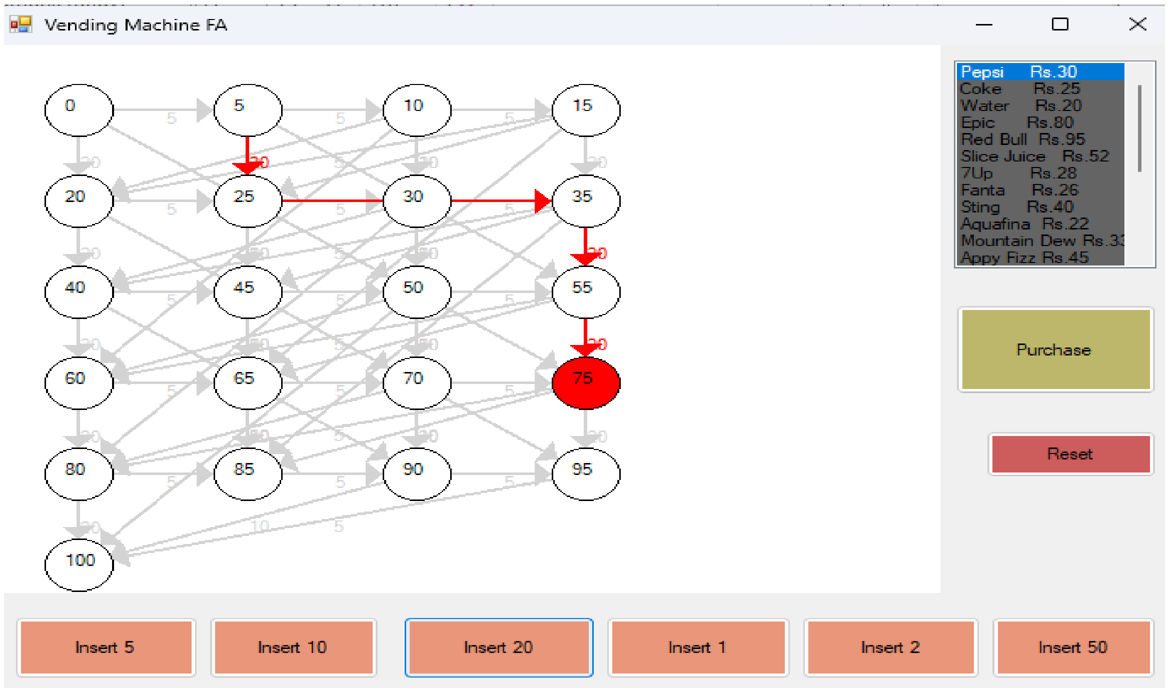
CODE AND OUTPUTS:

VendingMachine.cs:

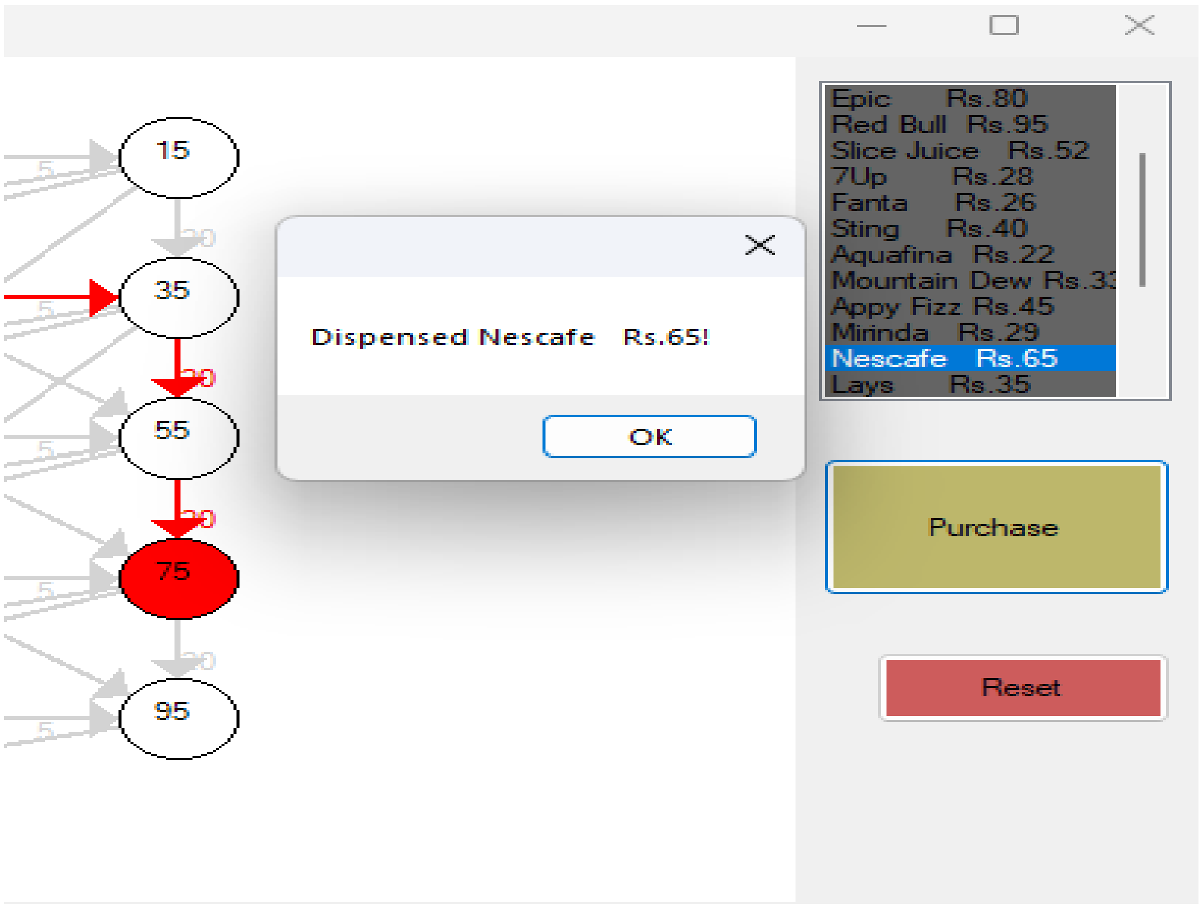
```
namespace VendingMachineFA
{
    public class Transition
    {
        public int From { get; set; }
        public int To { get; set; }
        public string Label { get; set; }

        public Transition(int from, int to, string label)
        {
            From = from;
            To = to;
            Label = label;
        }
    }

    public class Product
    {
        public string Name { get; set; }
        public int Price { get; set; }

        public override string ToString()
        {
            return $"{Name} ({Price} Rs)";
        }
    }
    public class VendingMachine
    {
        public int CurrentAmount { get; set; }
        public List<Product> Products { get; } = new List<Product>();
        public List<Transition> Transitions { get; } = new
List<Transition>();

        public void InsertCoin(int coin)
        {
            int from = CurrentAmount;
            CurrentAmount += coin;
            Transitions.Add(new Transition(from, CurrentAmount, $"{coin}"));
        }

        public bool PurchaseProduct(Product product)
        {
            if (product.Price > 100)
            {
                // Product too expensive to be dispensed
                return false;
            }

            if (CurrentAmount >= product.Price)
            {
                // Record transition from current state to "dispensed" state
                int from = CurrentAmount;
                Transitions.Add(new Transition(from, -1, $"Dispense
{product.Name}"));
                CurrentAmount = 0;

                return true;
            }
            return false;
        }

        public void Reset()
        {
            CurrentAmount = 0;
            Transitions.Clear();
        }
    }
}
```



Vending Machine FA
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Pepsi Rs.30
Coke Rs.25
Water Rs.20
Epic Rs.80
Red Bull Rs.95
Slice Juice Rs.52
7Up Rs.28
Fanta Rs.26
Sting Rs.40
Aquafina Rs.22
Mountain Dew Rs.33
Appy Fizz Rs.45
Purchase
Reset
Insert 5
Insert 10
Insert 20
Insert 1
Insert 2
Insert 50

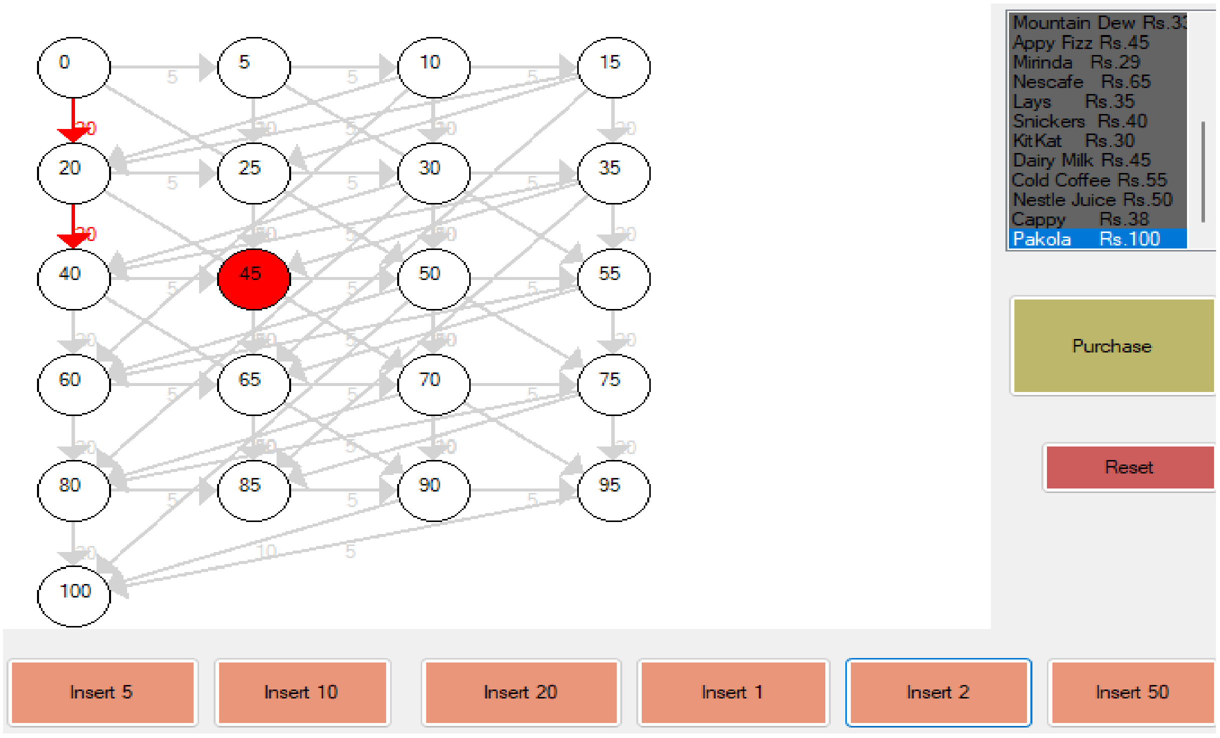


Vending Machine FA
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Pepsi Rs.30
Coke Rs.25
Water Rs.20
Epic Rs.80
Red Bull Rs.95
Slice Juice Rs.52
7Up Rs.28
Fanta Rs.26
Sting Rs.40
Aquafina Rs.22
Mountain Dew Rs.33
Appy Fizz Rs.45
Purchase
Reset
Insert 5
Insert 10
Insert 20
Insert 1
Insert 2
Insert 50



Dispensed Nescafe Rs.65!

Epic Rs.80
Red Bull Rs.95
Slice Juice Rs.52
7Up Rs.28
Fanta Rs.26
Sting Rs.40
Aquafina Rs.22
Mountain Dew Rs.33
Appy Fizz Rs.45
Mirinda Rs.29
Nescafe Rs.65
Lays Rs.35



Mountain Dew Rs.33
Appy Fizz Rs.45
Mirinda Rs.29
Nescafe Rs.65
Lays Rs.35
Snickers Rs.40
KitKat Rs.30
Dairy Milk Rs.45
Cold Coffee Rs.55
Nestle Juice Rs.50
Cappy Rs.38
Pakola Rs.100