Moore FSM Calculator Project Documentation

Project Overview

The Moore FSM Calculator is a software implementation of a **finite state machine (FSM)** designed to perform simple arithmetic calculations. This project simulates how a CPU control unit processes input using a **Moore machine approach**, where the outputs depend solely on the current state and not on the input.

The main idea of this project is to take academic topics such as **finite state machines, polymorphism, and object-oriented programming** and convert them into a real-world software application. Here, a calculator behaves according to well-defined states, transitions between them automatically, and produces the correct output for user input.

The project demonstrates **the practical application of computer science concepts** and shows how abstract theories can be translated into a working system that handles dynamic input while maintaining a clean and maintainable codebase.

Idea and Academic Connection

In academic courses, finite state machines are often taught as diagrams on paper, focusing on **states, transitions, and outputs**. This project transforms that theory into a **real software system**:

1) Each **state** in the FSM is implemented as a separate class inheriting from a common abstract base class.
2) The **context** class manages the current state and performs transitions based on input.
3) User input is processed character by character, mimicking how real hardware interprets signals.

This demonstrates that concepts such as **Moore and Mealy machines, state diagrams, and polymorphism** are not just theoretical; they can be applied to create robust and extendable software systems.

Object-Oriented Programming in the Project

The project uses **OOP principles extensively**:

> **Encapsulation:** Each state class (`clsS`, `clsAC`, `clsOpWait`, `clsCompute`, `clsError`) encapsulates the logic for handling input in that specific state.
>
> **Inheritance :** The `clsAbstractClass is a Super class for (clsS`, `clsAC`, `clsOpWait`, `clsCompute`, `clsError`) where these classes inherit from it.
>
> **Polymorphism:** The `clsAbstractClass` provides a common interface (`HandleInput`) for all states. The `currentState` pointer in the context class calls the correct derived class method at runtime.
>
> **Abstraction:** Users and other parts of the code interact only with the `clsContext` class, without needing to know the internal workings of each state.
>
> **Modularity:** Each state class is independent and can be extended or modified without affecting others.

Applying SOLID Principles

This project demonstrates several **SOLID design principles**:

> **Single Responsibility Principle (SRP):** Each state class has one responsibility — handling input for its state.
>
> **Open/Closed Principle (OCP):** New states or input types can be added by creating new classes without modifying existing ones.
>
> **Liskov Substitution Principle (LSP):** Each state can replace the abstract base class without breaking the system.
>
> **Interface Segregation Principle (ISP):** The abstract class only defines a single method (`HandleInput`), ensuring no unnecessary methods are forced on states.
>
> **Dependency Inversion Principle (DIP):** The context depends on the abstraction (`clsAbstractClass`) rather than concrete state implementations.

Clean Code and Software Architecture

The project adheres to **clean code practices**:

Clear class responsibilities and meaningful names (`clsContext`, `clsAC`, `clsCompute`).

Consistent method names that describe their actions (`HandleInput`, `Transition`, `enterState`).

Minimal global variables, all context data is encapsulated inside the `clsContext` object.

Memory management is handled carefully, with dynamic allocation for state objects and deletion of previous states.

The architecture follows a **classic State Pattern**:

1. **Context:** Maintains state, handles input, executes transitions.
2. **State Classes:** Encapsulate state-specific behavior.
3. **State Enum:** `clsStateType` defines possible states clearly.

This design ensures the project is **maintainable, extendable, and professional**.

States of the Calculator (State Diagram Overview)

The calculator operates in five main states:

1) **Start (clsS):** The initial state. Waits for the first digit or a sign (`+`/`-`). Builds the first number.
2) **Accumulate (clsAC):** Accumulates digits for the current number, handles operators or the equal sign.
3) **OperatorWait (clsOpWait):** Waits for the user to enter the next number after an operator.
4) **Compute (clsCompute):** Calculates the result when the equal sign is entered. Prepares the system for the next operation.
5) **Error (clsError):** Handles invalid input. Allows reset via `'C'` or `'c'`.

Each state class **handles input differently** and returns the **next state enum**, which the context uses to perform transitions.

Detailed Explanation of clsContext

The `clsContext` class is the **core of the FSM**. It manages **current state, input, and transitions**.

Key Variables

`clsAbstractClass* currentState` → Pointer to the active state object. Points to derived classes like `clsS` or `clsAC`.

`buildingnumber` → Accumulates digits as the user types.

`operand1` → Stores the first operand for operations.

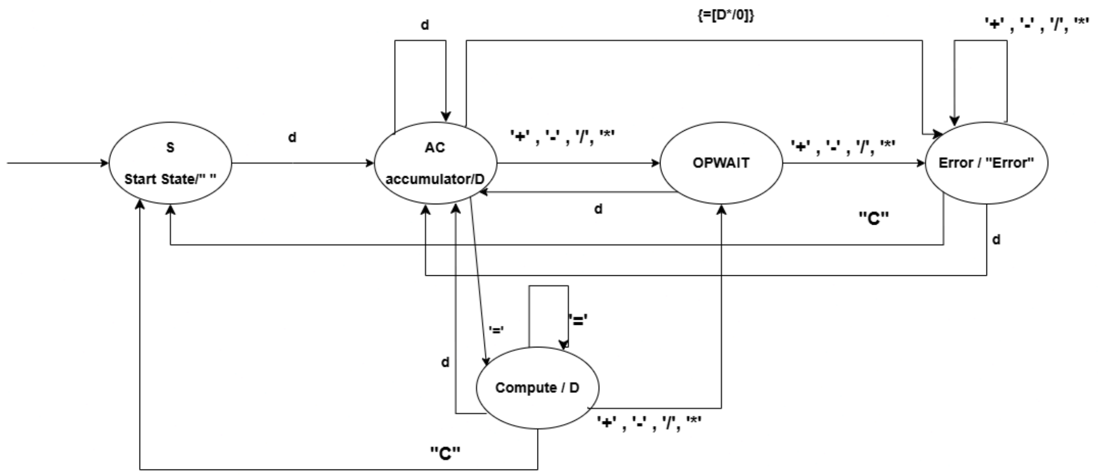
`lastnumber` → Stores the result of computations.

`operatorChar` → Stores the last operator entered.

`equal` → Tracks if the equal sign was entered.

`display` → Holds the string shown to the user.

Moore Calculator Diagram



The previous Diagram illustrates the Moore State Machine Calculator

Key Methods

***SetCurrentState**(clsAbstractClass newState):**

Updates `currentState` pointer to a new state object.

HandleInput(string &token):
Delegates input to the current state via `currentState->HandleInput(token, *this)`. Receives the next state enum and calls `Transition()`.

Transition(clsStateType nextState):
Deletes the old state object, allocates a new one according to `nextState`, and calls `enterState()` to update the display. This is where the FSM **actually moves between states**.

enterState(clsStateType next):
Updates the `display` and resets or prepares context data depending on the state. For example, in `Accumulate`, it shows the current number being typed; in `Compute`, it displays the last result.

compute(int a, char op, int b):
Performs basic arithmetic based on the operator: addition, subtraction, multiplication, division.

getdisplay():
Returns the current display string for GUI or console output.

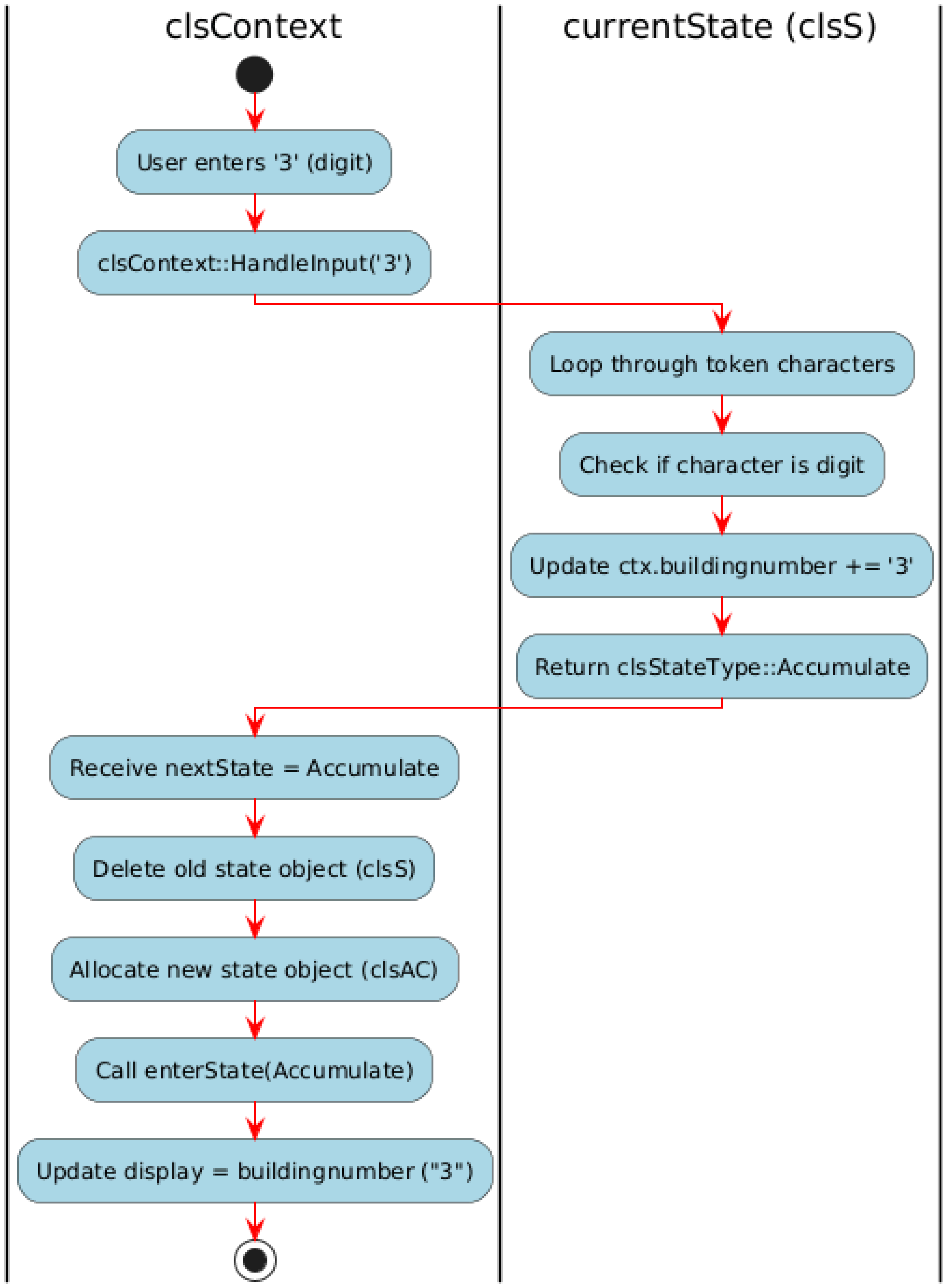
Pointer and Transition Logic

`currentState` is a pointer to `clsAbstractClass`, but at runtime it points to a **derived state object** (polymorphism).

The **state object never directly changes states**. It only returns a `clsStateType`.

`clsContext` handles the **actual transition**: deletes the old object, creates the new one, updates the display.

This design ensures **clean separation of responsibilities** and **safe memory management**.



This is an Active Diagram shows how the transition occur

now if we let the currentState for example is clsS so what will happen?

Step 0: Initial Setup

clsContext ctx;

ctx.SetCurrentState(new clsS()); // Start state

`currentState` → points to `clsS` object.

`clsContext` data is at default values

buildingnumber = ""
operand1 = 0, lastnumber = 0, operatorChar = '0'
Step 1: User inputs a number (e.g., "3")
std::string token = "3";
ctx.HandleInput(token);

Inside clsContext::HandleInput:

```
clsStateType next = currentState->HandleInput(token, *this);
Transition(next);
```

Step 2: Polymorphic call to clsS::HandleInput

```
clsStateType clsS::HandleInput(std::string Token, clsContext &ctx)
```

Loop through Token ('3'):

1. '3' is a digit → add to buildingnumber:

   `ctx.buildingnumber += '3';`

2. Return next state:

   `return clsStateType::Accumulate;`

Note: clsS doesn't perform the transition itself. It just requests Accumulate by returning the enum.

Step 3: clsContext::Transition(next) executes

   `Transition(clsStateType::Accumulate);`

   Inside Transition:

1. Delete the old state: `if(currentState) delete currentState;`
2. Create the new state:

```
    case clsStateType::Accumulate:
        SetCurrentState(new clsAC());
```

3.Update display via `enterState()`:

```
     enterState(nextState);
     display = buildingnumber.empty() ? "0" : buildingnumber;
```

Transition is Completed

This project implements a Finite State Machine (FSM)-based calculator using a C++ DLL and a C# GUI.

- **C++ DLL → contains the FSM calculator logic**
- **C# GUI → user interface that dynamically calls the DLL functions**

This separation ensures modularity, memory safety, and easy maintenance.

Project Structure

```
FSM-Moore-Calculator/
├─ FSMCalculatorMachineDLL/       # C++ DLL project
|   ├─ dllmain.cpp                # DLL entry point
|   ├─ csFSMLinkercpp.h           # Exported functions interface
|   ├─ csFSMLinkercpp.cpp         # Implementation of FSM logic
```

```
│   └─ x64/Release/FSMCalculatorMachineDLL.dll   # Generated DLL
│
└─ FSMCalculatorGUI/                    # C# GUI project
    ├─ CalculatorForm.cs                # Main form and UI
    ├─ CalculatorBackend.cs             # Wrapper class for DLL
    └─ bin/Debug/                       # Copy DLL here
        └─ FSMCalculatorMachineDLL.dll
```

C++ DLL Explanation

Files

- `dllmain.cpp` → standard Windows DLL entry point
- `csFSMLinkercpp.h` → declares exported functions for C#
- `csFSMLinkercpp.cpp` → FSM calculator logic

Why DLL is Important

1) Allows the **C++ FSM logic** to be reused by C# GUI
2) Keeps the GUI code simple and modular
3) Supports memory management through explicit context creation/deletion

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Build Instructions (C++ DLL)

1. Open FSMCalculatorMachineDLL.sln in Visual Studio
2. Set **Configuration** → Release or Debug
3. Set **Project Properties** → **Configuration Type** → Dynamic Library (.dll)
4. Set **Target Architecture** → `x64` (must match C# GUI)
5. Build project → DLL is generated at
6. Copy the `.dll` into **C# GUI bin folder**

Using the DLL in C# GUI

CalculatorBackend Wrapper

Provides safe, object-oriented access to DLL:

```
CalculatorBackend backend = new
CalculatorBackend();

backend.HandleInput("5");

backend.HandleInput("+");

backend.HandleInput("3");

string result = backend.CalculateResult(); //
returns "8"

backend.Dispose();
```

Architecture Matching

DLL and C# GUI **must have the same architecture**: x64 ↔ x64 or x86 ↔ x86

Set in **Project Properties** → **Build** → **Platform target.**

then you can run your GUI.