Software Design Patterns

Continuous Assessment 2 – CA2

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Design and Responsibilities Assignment Patterns

Question 1

a) Before choosing a specific pattern, I will analyze **the type** of problem that we are facing here. The learning material distinguishes between **two important kinds** of patterns for this unit:

- **Responsibility Assignment Patterns** (WHO should do something): Helps in decide which class should take on which responsibility. Useful when assigning logic on who creates an object, who handles a request or who has enough knowledge to perform an operation.
- **Design Patterns** (HOW to do something technically): These are for offering reusable solutions to common software design problems specially at the technical level. Useful when we need to define how to control access to an object, how to decouple component or how to handle the creation of objects.

In our exercise, the problem is described as the need to define **how to manage a unique, globally accessible and critical configuration in a way that prevents inconsistencies across the system**. As we can see, this is a HOW to do technical problem, focused on the structure and control of a single shared instance, which clearly falls into the category of *design patterns*.

After classifying this problem, I will evaluate which of the available **design patterns** in the learning material is the most suitable for our use case:

1. The statement of this first question tells us that:
    - The configuration is critical to the functioning of the system.
    - It must be **managed in a unique wa**y (only one instance must exist).
    - It must be **accessible globally** (from anywhere in the system).
    - It must ensure **is consumed and modified in a secure way** and avoid inconsistencies.

2. Based on this description, we can highlight three **key technical needs**:
    - **Unique management**
    - **Global accessibility**
    - **Consistency and safety**

3. We can now discard some of the patterns that may be not full aligned with these key technical needs:
    - Patterns like **Strategy**, **Command** or **State** are more for encapsulate behaviour or manage dynamic changes but *they don't provide global access or unique management.*
    - **Iterator**, **Adapte**r, **Decorator** or **Proxy** are more for structural and traversal decision but *not related with the global system coordination and they don't ensure a single instance.*
    - **Factory Method**, **Template Method** and **Abstract Server** are more focused on how to create objects and server abstraction. *They are more for deciding how to create multiple objects rather than managing the global configuration.*
    - **Observer** is more for automatic updates and **Null Object** helps avoid null checks, but *they don´t guarantee a unique instance or a secure modification.*
    - **Facade** simplifies the interface usage but *doesn't provide by itself unique management or access control.*

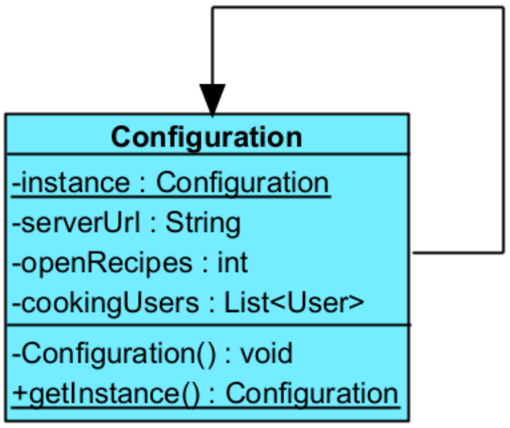
4. So, the pattern that may address all the three key technical needs is the **Singleton** pattern. In the material it is mentioned that this pattern "*ensures for a class that can only be one instance"*, which is exactly what is expected in this Guided Cooking system requirement. Even though the statement is mentioning the "coordination of the execution of all the devices" which can in my opinion easily lead to misunderstand as the need of coordinate actions between objects applying patterns like **Command**, **Mediator** or **Observer**, my decision is focused on the need of **one unique instance of configuration, accessible from any part of the system and consistent**.

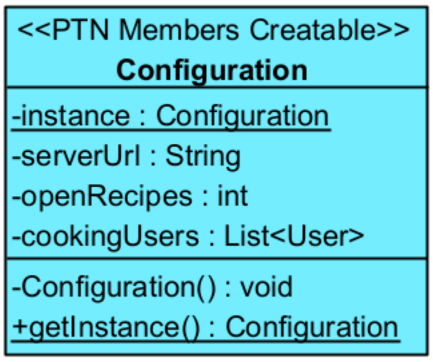
5. Advantages of applying **Singleton** pattern compared with other alternatives:
   - Ensure there's only one configuration object in the whole system.
   - Allows any part of the system, such as the device controllers or the recipe managers, to access the same configuration.
   - It will help to avoid problems like duplication or conflict settings.
   - It is a simple and practical solution, easy to apply and without the need of any extra change in other classes.

6. Disadvantages to be considered:
   - It is difficult to replace and hard for unit tests.
   - If the system is using multiple threads, and several devices connect at the same time, this pattern will need and extra configuration to not break (thread safe).

Based on this comparative analysis of the pattern alternatives offered in the learning material, I found the **Singleton** pattern as the best choice to apply in this use case.

b) NOTE: Unfortunately, I didn´t find any UML Singleton representation example in the learning material nor the solution examples. I searched on internet different ways to represent it. I am adding here two different options found:


Configuration
-instance : Configuration
-serverUrl : String
-openRecipes : int
-cookingUsers : List<User>
-Configuration() : void
+getInstance() : Configuration


<<PTN Members Creatable>>
Configuration
-instance : Configuration
-serverUrl : String
-openRecipes : int
-cookingUsers : List<User>
-Configuration() : void
+getInstance() : Configuration

***Option 1**: Self reference representing the class contains an instance of itself.*

Source: https://refactoring.guru/design-patterns/singleton#structure

***Option 2**: Using Visual Paradigm <<PTN Members Createtable>> Stereotype indicating that the class may contain aditional methods beyond the strictly neccesary for the Singleton pattern implementation.*

Source: https://www.visual-paradigm.com/tutorials/singletonpattern.jsp c)

```
public class Configuration {
    // Static attribute having the single instance of the class
    private static volatile Configuration instance;

    // Configuration data attributes
    private String serverUrl;
    private Integer openRecipes;
    private ArrayList<User> cookingUsers;

    // Private constructor to prevent instantiation from outside
    private Configuration() {
        this.serverUrl = "";
        this.openRecipes = 0;
        this.cookingUsers = new ArrayList<User>();
    }

    // Static method to access the single instance (thread safe)
    public static Configuration getInstance() {
        if (instance == null) {
            synchronized (Configuration.class) {
                if (instance == null) {
                    instance = new Configuration();
                }
            }
        }
        return instance;
    }
}
```

***NOTE**: Since the statement mentions multiple users concurrently connecting, thread safe mode was added by including **volatile** and **synchronized**.*

Question 2

a) In this case, the problem consists of designing a system that **allows users to explore their collections of saved recipes in multiple, flexible ways** such as filtering by vegan recipes, sorting by cooking or adding new visualizations and export options in the future.

This is also a clear “HOW to do” technical problem, because we must **define a technical way to allow the flexible exploration of the collections** in a maintainable and extensible manner.

After classifying this problem, I will evaluate which of the available design patterns is the most suitable for our use case:

1. The question statement highlights the following requirements:
    - We want to define **different strategies for exploring recipes** *(filtering, sorting, etc).*
    - The system must **allow for future addition of new strategies** without modifying the existing code.
    - There may be **multiple filters or criteria** with its own logic.

2. From this definition, we can extract these **key technical needs**:
    - **Flexibility** *(to define and apply different exploration behaviours).*
    - **Separation of concerns** *(the logic for exploring should be independent from the main collection).*
    - **Open/Closed principle** *(the system must be open to new strategies but closed for modification of existing logic).*

3. Based on all these, we can discard several patterns alternatives from our learning material catalogue:
    - **Adapter** and **Facade** are structural patterns used more for interface compatibility or simplification, *but they are not direct related with flexibility behaviour as we need*.
    - **Command** and **Observer** may offer extensibility (like trigger actions or reacting to events) but *they don’t address the need of selecting different exploration behaviours*.
    - **Decorator** is suitable for adding responsibilities dynamically *but not for changing the collection traversal logic as it is required*.

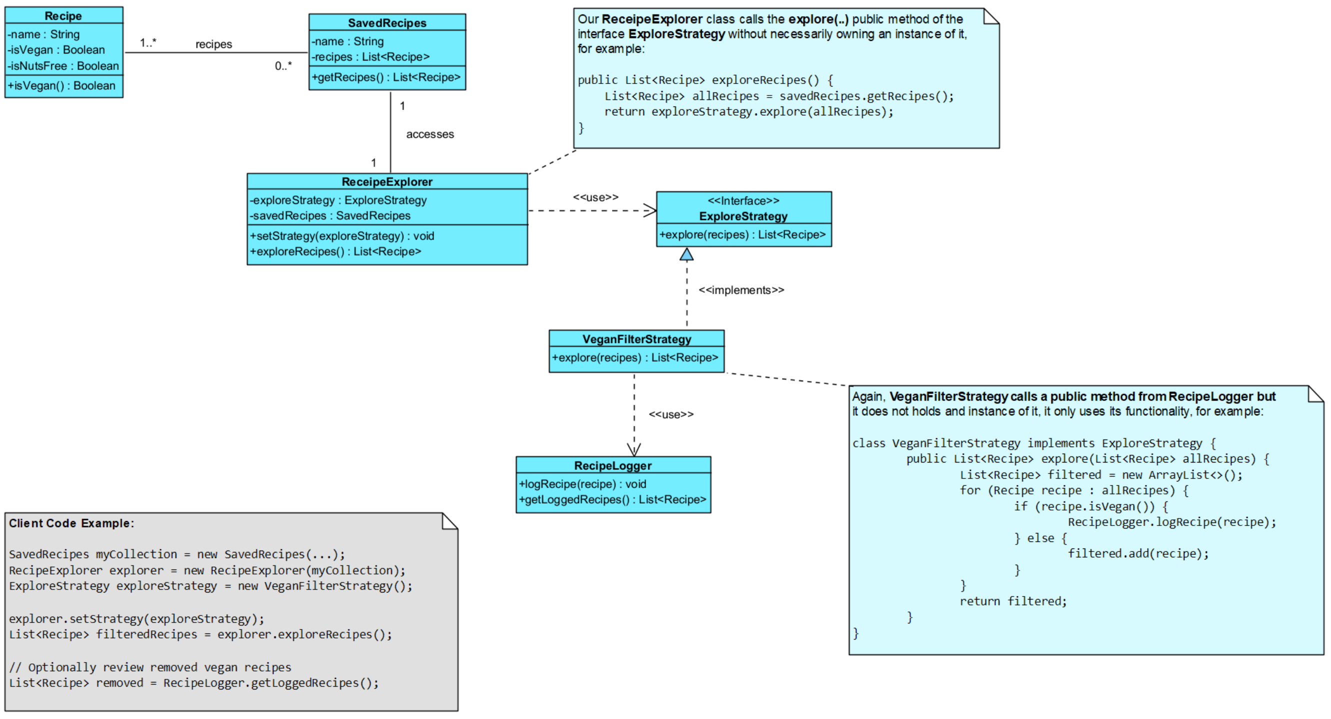
4. **Template Method** and **Strategy** patterns seems to be the most suitable for this use case. The learning material mentions that *“The Strategy design pattern allows solving very similar problems to those that the Template method pattern solves …”*. So, analysing these two patterns options, we may say that the **Template Method** would partially work if we provided a fixed algorithm, but as it is described in the material explanation, it requires inheritance and a predefined algorithm structure, which will limit the flexibility and will requires subclassing every time a new strategy is needed. On the other hand, the **Strategy** pattern is specifically designed for this kind of scenario because it allows the algorithms (in our case the exploration logic) to be defined in a family of classes. So, these strategies can be “interchanged at runtime” and based on the user’s preference. We can have a core class that doesn´t need to know how each strategy works, it just used the selected one.

5. Advantages of applying the **Strategy** pattern compared with other alternatives:
   - Supports **open/closed principle** since new exploration strategies can be added without modifying the existing classes.
   - We will **prioritize composition over inheritance** since strategies are passed as object rather than implemented by subclasses.
   - Allows users or system components to dynamically select how they want to explore the recipe collections.
   - The **exploring logic implemented**, for example veganFilterStrategy is **decoupled** from SavedRecipes class (better for maintainability).

6. Disadvantages to be considered:
   - If there are too many strategies of exploration classes, we will have code that is difficult to navigate and understand.
   - Clients must know the differences between strategies to be able to select a proper one (naming is key here).
   - If we have only few algorithms and they do not change, we may overcomplicate the program with the new classes and interfaces.

Based on this comparative analysis of the patterns alternatives offered in the learning material, I found the **Strategy** pattern as the best choice to apply in this use case.

A possible class diagram, that can be then represented in the sequence diagram requested, can be:


Recipe
-name : String
-isVegan : Boolean
-isNutsFree : Boolean
+isVegan() : Boolean
1..*
recipes
0..*
SavedRecipes
-name : String
-recipes : List<Recipe>
+getRecipes() : List<Recipe>
1
accesses
1
ReceipeExplorer
-exploreStrategy : ExploreStrategy
-savedRecipes : SavedRecipes
+setStrategy(exploreStrategy) : void
+exploreRecipes() : List<Recipe>
<<use>>
<<Interface>>
ExploreStrategy
+explore(recipes) : List<Recipe>
<<implements>>
VeganFilterStrategy
+explore(recipes) : List<Recipe>
<<use>>
RecipeLogger
+logRecipe(recipe) : void
+getLoggedRecipes() : List<Recipe>

Our **ReceipeExplorer** class calls the **explore(..)** public method of the interface **ExploreStrategy** without necessarily owning an instance of it, for example:

```
public List<Recipe> exploreRecipes() {
    List<Recipe> allRecipes = savedRecipes.getRecipes();
    return exploreStrategy.explore(allRecipes);
}
```

Again, **VeganFilterStrategy calls a public method from RecipeLogger but** it does not holds and instance of it, it only uses its functionality, for example:

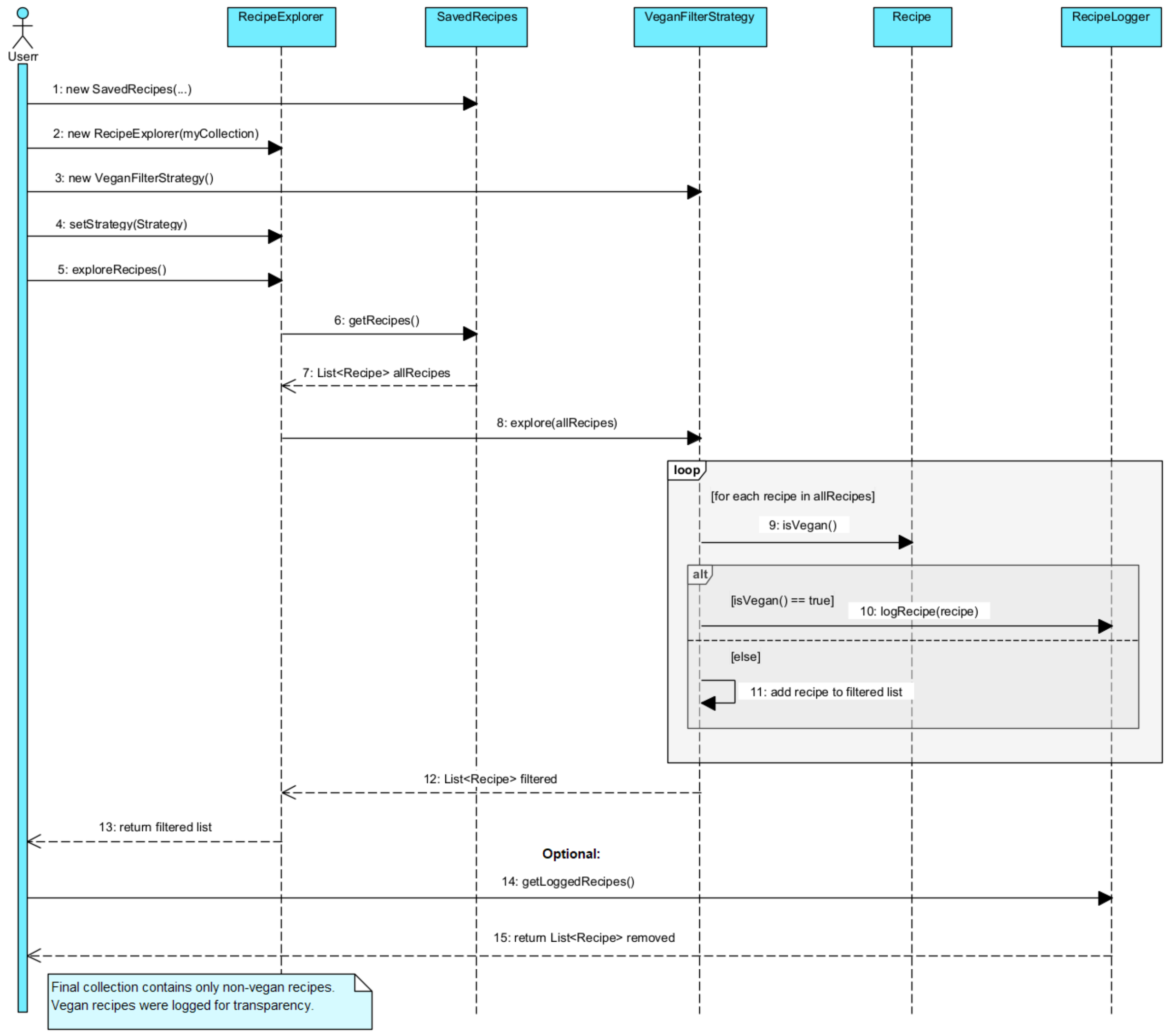
```
class VeganFilterStrategy implements ExploreStrategy {
        public List<Recipe> explore(List<Recipe> allRecipes) {
                List<Recipe> filtered = new ArrayList<>();
                for (Recipe recipe : allRecipes) {
                        if (recipe.isVegan()) {
                                RecipeLogger.logRecipe(recipe);
                        } else {
                                filtered.add(recipe);
                        }
                }
                return filtered;
        }
}
```

Client Code Example:

```
SavedRecipes myCollection = new SavedRecipes(...);
RecipeExplorer explorer = new RecipeExplorer(myCollection);
ExploreStrategy exploreStrategy = new VeganFilterStrategy();

explorer.setStrategy(exploreStrategy);
List<Recipe> filteredRecipes = explorer.exploreRecipes();

// Optionally review removed vegan recipes
List<Recipe> removed = RecipeLogger.getLoggedRecipes();
```

- *__ReceipeExplorer__ represent the __context__ of the strategy pattern. It receives the collection and a strategy and execute __exploreRecipes()__ that calls internally to strategy.explore(…).*
- *__ExploreStrategy__ represent the __Interface__ that defines the contract for the strategies.*
- *__VeganFilterStrategy__: Concrete strategy implementation of __ExploreStrategy__. In this use case it filters vegan recipes and uses __RecipeLogger__ to log the ones it removes.*
- *__RecipeLogger:__ Class responsible for logging discarded recipes (vegan ones in this case).*

**Source: https://refactoring.guru/design-patterns/strategy#structure* b)


Userr
RecipeExplorer
SavedRecipes
VeganFilterStrategy
Recipe
RecipeLogger
1: new SavedRecipes(...)
2: new RecipeExplorer(myCollection)
3: new VeganFilterStrategy()
4: setStrategy(Strategy)
5: exploreRecipes()
6: getRecipes()
7: List<Recipe> allRecipes
8: explore(allRecipes)
loop
[for each recipe in allRecipes]
9: isVegan()
alt
[isVegan() == true]
10: logRecipe(recipe)
[else]
11: add recipe to filtered list
12: List<Recipe> filtered
13: return filtered list
Optional:
14: getLoggedRecipes()
15: return List<Recipe> removed
Final collection contains only non-vegan recipes.
Vegan recipes were logged for transparency.

Question 3

a) Before choosing a specific pattern, I will analyse the type of problem that we are facing in this question:

We are required here to design a system that can supports flexible execution of commands (like start, pre-heat, stop, etc.) on smart cooking devices, with the additional need of supporting undo and redo operations.
This is clearly a **technical "HOW to do" problem**, since we are focused on how to technically organize and control the actions, rather than assigning responsibilities.

After classifying this problem, I will evaluate which of the available design patterns is the most suitable for our use case:

1. The question statement highlights the following requirements:
   - We want to define **a variety of commands that needs to be executed on devices.**
   - The system must **allow for future addition of new commands** without modifying the existing code.
   - There must be a **history of executed commands** to support undo and redo the operations.

2. From these requirements, we can extract these **key technical needs**:
   - **Flexibility** (*to encapsulate each command as a reusable objects*).
   - **Extensibility** *(to support adding new command types easily).*
   - **History management** *(to implement undo/redo operations).*

3. Based on all these, we can discard several patterns alternatives from our learning material catalogue:
   - Patterns like **Observer** or **Strategy** are more useful for event notification or variation of the algorithms *but don't focus on supporting undo/redo logic.*
   - **Template Method, Adapter,** or **Facade** help with reusability and simplification*, but do not encapsulate executable actions as it is required.*
   - **Singleton, Factory Method** are more related to object control, *but don't offer action tracking history.*

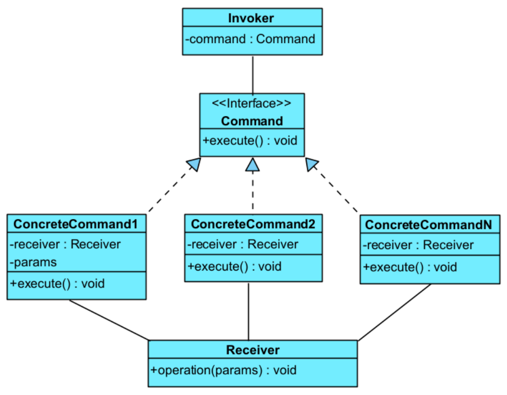
4. The pattern that could best satisfy all the needs described above, is the **Command** pattern. As it is mentioned in the Learning Material, this pattern is useful when "*we want to handle calls to operations as objects...". It also* allows for a centralized execution mechanism (like the remote-control class) and supports flexible architecture where adding a new command will not require to change the existing code (open/closed principle).

5. Main reasons for applying the **Command** pattern in our use case:
   - Allows each device instruction to be **encapsulated as a separate command** class.
   - Make it easy to **implement the undo and redo** operations required.
   - **It provides a central mechanism for executing the commands,** which is what is expected in this idea of a remote control for giving instructions to the devices.
   - **It will ensure that the system is open for extension** (creating new command classes) and **closed for modification**, because we don´t need to change the existing command execution logic to add new instructions.
   - It is perfectly **aligned with the requirement of flexible control** and historical tracking of device actions, allowing us to implement the most advanced features described such as switching back from fast pressure to slow, etc.

Based on the analysis of the requirements and different pattern characteristics described, I believe that the **Command** pattern is the most appropriate pattern choice to address the problem presented in our use case. It will provide a clean, extensible, and maintainable way to control the smart cooking devices, including support for undo and redo functionalities.

b) To be able to implement this pattern in our case, I applied the following reasoning:

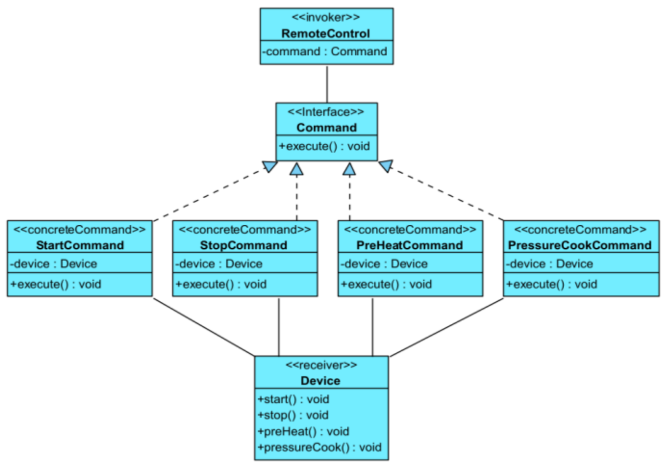
Step 1 *– Define base structure of the Command pattern*



First, I defined a mental model with the basic structure of the **Command** pattern and its components:

- The **Invoker** who sends the command.
- The **Command** interface that defines what will be executed.
- the **ConcreteCommand** classes that implements various kind of requests and pass the call to one of the business logic objects (the **Receiver**).
- The **Receiver** who actually does the real work.
  **When it is required for the operations, it receives some parameters from the commands.*

Step 2 *- Adapt the model to the smart devices use case*



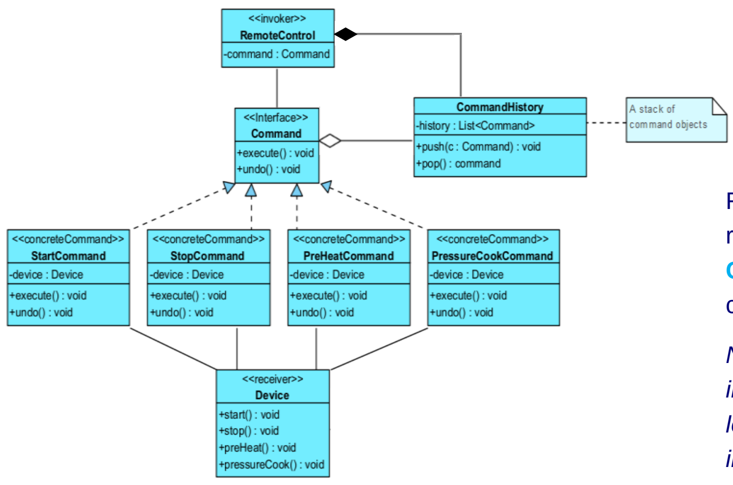
Then, I adapted this model to the classes names that fits the smart devices system proposed:

- The **Invoker** became **RemoteControl**.
- The **Receiver** became **Device**.
- the **ConcreteCommand** classes are the ones described in the statement.

This helped to test **how the pattern works in practice** and imagine how the system would behave when a user sends a command to a device.

This confirms **that the system will be flexible**, meaning that if we want to add a new action, we can just write a new command class.

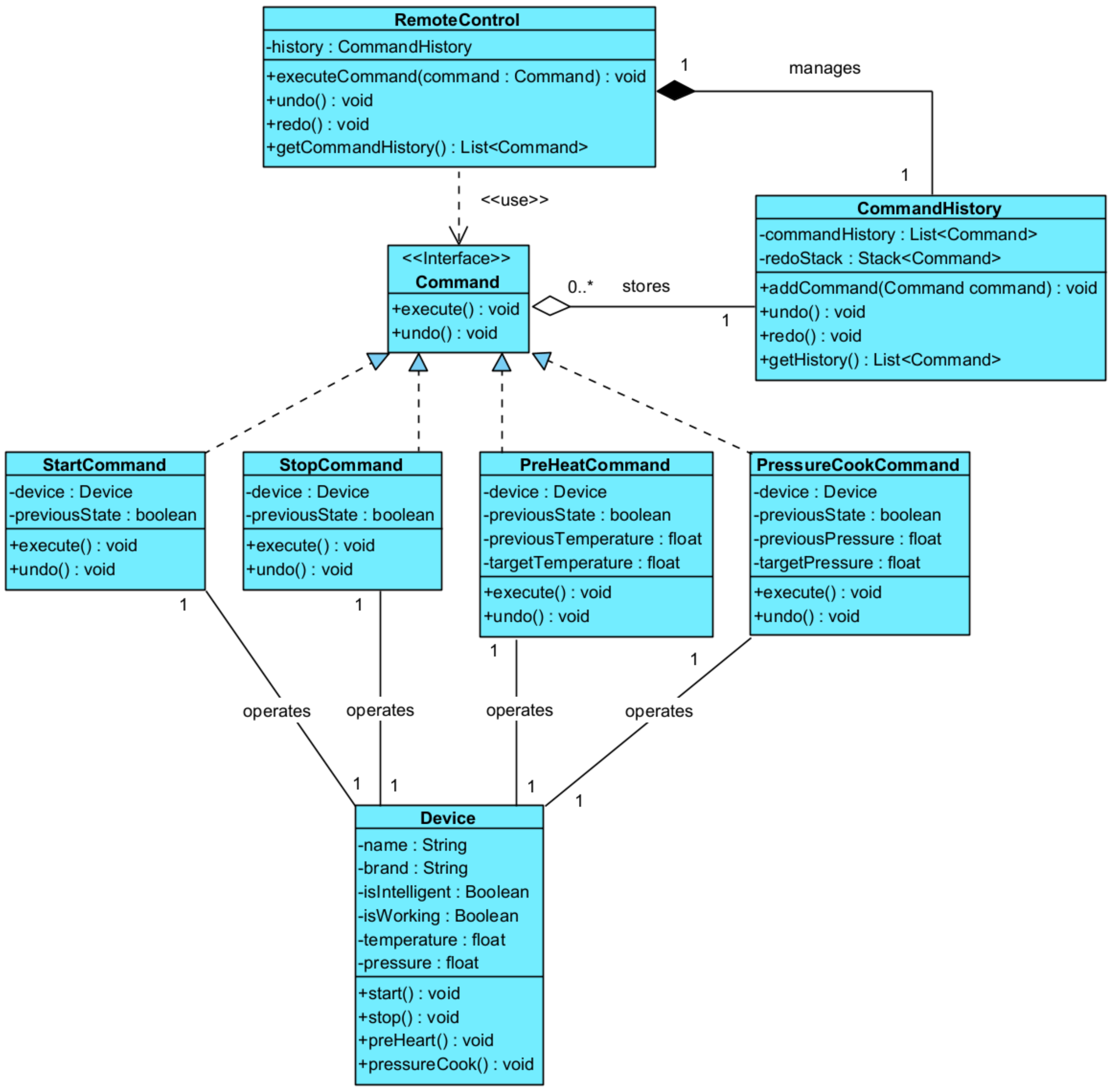
Step 3 *- Add new class for history features*



Finally, I added the history and undo/redo support features required in the assignment. But to do so, I added a separate **CommandHistory** class that will hold a list of executed commands in a stack.

NOTE: We could have added these functionalities directly in the ***RemoteControl*** *class, but the idea of separating this logic in a new class is to avoid mixing the responsibilities inside the invoker and keep things clean.*

Based on this reasoning, I propose the following class diagram for our use case:



NOTE: I am consius that the Device class is handling many responsabilities possible violating the SRP. We could have implemented a DeviceState class or any other startegy, but to not overcomplicate the exercise, and focusing on the stament problem, I decided to keep this simple.

c)

```
// Invoker Class
public class RemoteControl {
    private CommandHistory history;

    public RemoteControl() {
        this.history = new CommandHistory();
    }

    // Execute the command and is added to the history
    public void executeCommand(Command command) {
        command.execute();
        history.addCommand(command);
    }

    // Delegate the operations to the Command History
    public void undo() {
        history.undo();
    }

    public void redo() {
        history.redo();
    }

    public List<Command> getCommandHistory() {
        return history.getHistory();
    }
}
```

```java
// Class for managing the history of commands execution
public class CommandHistory {
    private List<Command> commandHistory = new ArrayList<>();
    private Stack<Command> redoStack = new Stack<>();
    private int currentIndex = -1;

    // Add a command to the history
    public void addCommand(Command command) {
        // Clear any commands in the redo stack when a new command is executed
        if (!redoStack.isEmpty()) {
            redoStack.clear();
        }

        commandHistory.add(command);
        currentIndex = commandHistory.size() - 1;
    }

    // Undo the last executed command
    public void undo() {
        if (currentIndex >= 0) {
            Command command = commandHistory.get(currentIndex);
            command.undo();
            redoStack.push(command);
            currentIndex--;
        } else {
            System.out.println("Nothing to undo");
        }
    }

    // Redo command
    public void redo() {
        if (!redoStack.isEmpty()) {
            Command command = redoStack.pop();
            command.execute();
            currentIndex++;
        } else {
            System.out.println("Nothing to redo");
        }
    }

    // Return the commands history
    public List<Command> getHistory() {
        return new ArrayList<>(commandHistory);
    }
}
```

```
// Command Interface
public interface Command {
    void execute();
    void undo();
}

// Receiver
public class Device {
    private String name;
    private String brand;
    private boolean isIntelligent;
    private boolean isWorking;
    private float temperature;
    private float pressure;

    public Device(String name, String brand, boolean isIntelligent) {
        this.name = name;
        this.brand = brand;
        this.isIntelligent = isIntelligent;
        this.isWorking = false;
        this.temperature = 0;
        this.pressure = 0;
    }

    public void start() {
        isWorking = true;
        System.out.println(name + ": started.");
    }

    public void stop() {
        isWorking = false;
        System.out.println(name + ": stopped.");
    }

    public void preHeat(float temp) {
        temperature = temp;
        System.out.println(name + ": preheated to " + temp);
    }

    public void pressureCook(float pressure) {
        this.pressure = pressure;
        System.out.println(name + ": pressure cook at " + pressure);
    }
    public float getTemperature() {
        return temperature;
    }

    public float getPressure() {
        return pressure;
    }

    public boolean isWorking() {
        return isWorking;
    }
}

// StartCommand
public class StartCommand implements Command {
    private Device device;
    private boolean previousState;

    public StartCommand(Device device) {
        this.device = device;
    }

    public void execute() {
        previousState = device.isWorking();
        if (!previousState) {
            device.start();
        } else {
            System.out.println(device.getName() + " was already started.");
        }
    }

    public void undo() {
        if (!previousState) {
            device.stop();
        }
    }
}
```

```java
// StopCommand
public class StopCommand implements Command {
    private Device device;
    private boolean previousState;

    public StopCommand(Device device) {
        this.device = device;
    }

    public void execute() {
        previousState = device.isWorking();
        if (previousState) {
            device.stop();
        } else {
            System.out.println(device.getName() + " was already stopped.");
        }
    }

    public void undo() {
        if (previousState) {
            device.start();
        }
    }
}

// PreHeatCommand
public class PreHeatCommand implements Command {
    private Device device;
    private boolean previousState;
    private float previousTemperature;
    private float targetTemperature;

    public PreHeatCommand(Device device, float targetTemperature) {
        this.device = device;
        this.targetTemperature = targetTemperature;
    }

    public void execute() {
        previousState = device.isWorking();
        previousTemperature = device.getTemperature();
        device.setTemperature(targetTemperature);
    }

    public void undo() {
        device.setTemperature(previousTemperature);
    } }
```

```
// PressureCookCommand
public class PressureCookCommand implements Command {
    private Device device;
    private boolean previousState;
    private float previousPressure;
    private float targetPressure;

    public PressureCookCommand(Device device, float targetPressure) {
        this.device = device;
        this.targetPressure = targetPressure;
    }

    public void execute() {
        previousState = device.isWorking();
        previousPressure = device.getPressure();
        device.setPressure(targetPressure);
    }

    public void undo() {
        device.setPressure(previousPressure);
    }
}
```

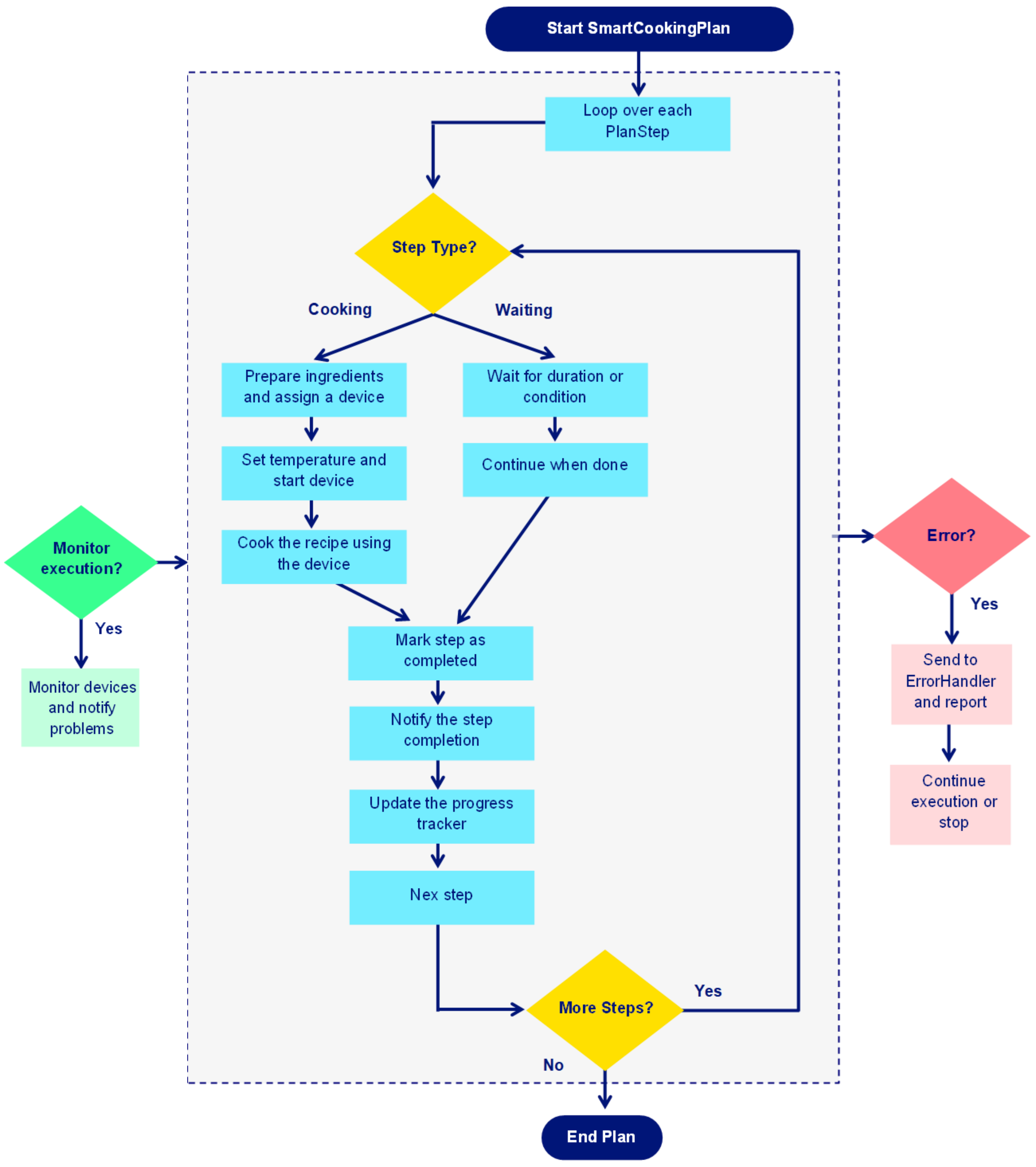
NOTE*: We assume all classes will define some getters and setters since in some examples are used but not defined.*

Usage Example:

```
public class Main {

    public static void main(String[] args) {

        // Create the Smart Device

        Device pressureCooker = new Device("Pressure Cooker", "Phillips", true);


        // Create the remote control

        RemoteControl remote = new RemoteControl();


        // Send the command to the device

        Command start = new StartCommand(pressureCooker);

        remote.executeCommand(start); // Pressure Cooker: started.


        // Preheat to 180 grades

        Command preheat = new PreHeatCommand(pressureCooker, 180.0f);

        remote.executeCommand(preheat); // Pressure Cooker: preheated to 180.0


        // Define slow pressure

        Command slowPressure = new PressureCookCommand(pressureCooker, 1.0f);

        remote.executeCommand(slowPressure); // Pressure Cooker: pressure cook at 1.0


        // Change to fast pressure but we decide to undo

        Command fastPressure = new PressureCookCommand(pressureCooker, 3.0f);

        remote.executeCommand(fastPressure); // Pressure Cooker: pressure cook at 3.0


        // User realizes it was too strong and undo

        remote.undo(); // Pressure Cooker: pressure cook at 1.0

        // Then decide to redo the change

        remote.redo(); // Pressure Cooker: pressure cook at 3.0


        // Finally stops the device

        Command stop = new StopCommand(pressureCooker);

        remote.executeCommand(stop); // Pressure Cooker: stopped.

}
```

Question 4

a) To implement the **Smart Cooking Plan** feature, we should design a system that can organize and execute complex cooking steps using smart devices like ovens or pots as it is described in the statement. These plans may include actions like starting a recipe, setting up a device, and waiting for results (for example, waiting for a cake to bake). To support the execution of this system in a clean and scalable way, we must ensure among others, high cohesion, low coupling and the use of suitable design patterns. A possible workflow could be:


Start SmartCookingPlan
Loop over each PlanStep
Step Type?
Cooking
Waiting
Prepare ingredients and assign a device
Set temperature and start device
Cook the recipe using the device
Wait for duration or condition
Continue when done
Mark step as completed
Notify the step completion
Update the progress tracker
Nex step
More Steps?
Yes
No
End Plan
Monitor execution?
Yes
Monitor devices and notify problems
Error?
Yes
Send to ErrorHandler and report
Continue execution or stop

1. Class Design Overview

To organize the classes, I will put at the centre the **SmartCookingPlan** class that will hold a list of steps, each represented by a subclass of **PlanStep** (a template abstract class sharing common code). Each step will do something different like cooking a recipe or waiting for something to finish.

As we already mentioned, the **PlanStep** class will define a **template method** called **execute()** which defines the full structure of how *each step* should run but allowing *each step* type to customize parts of that process.

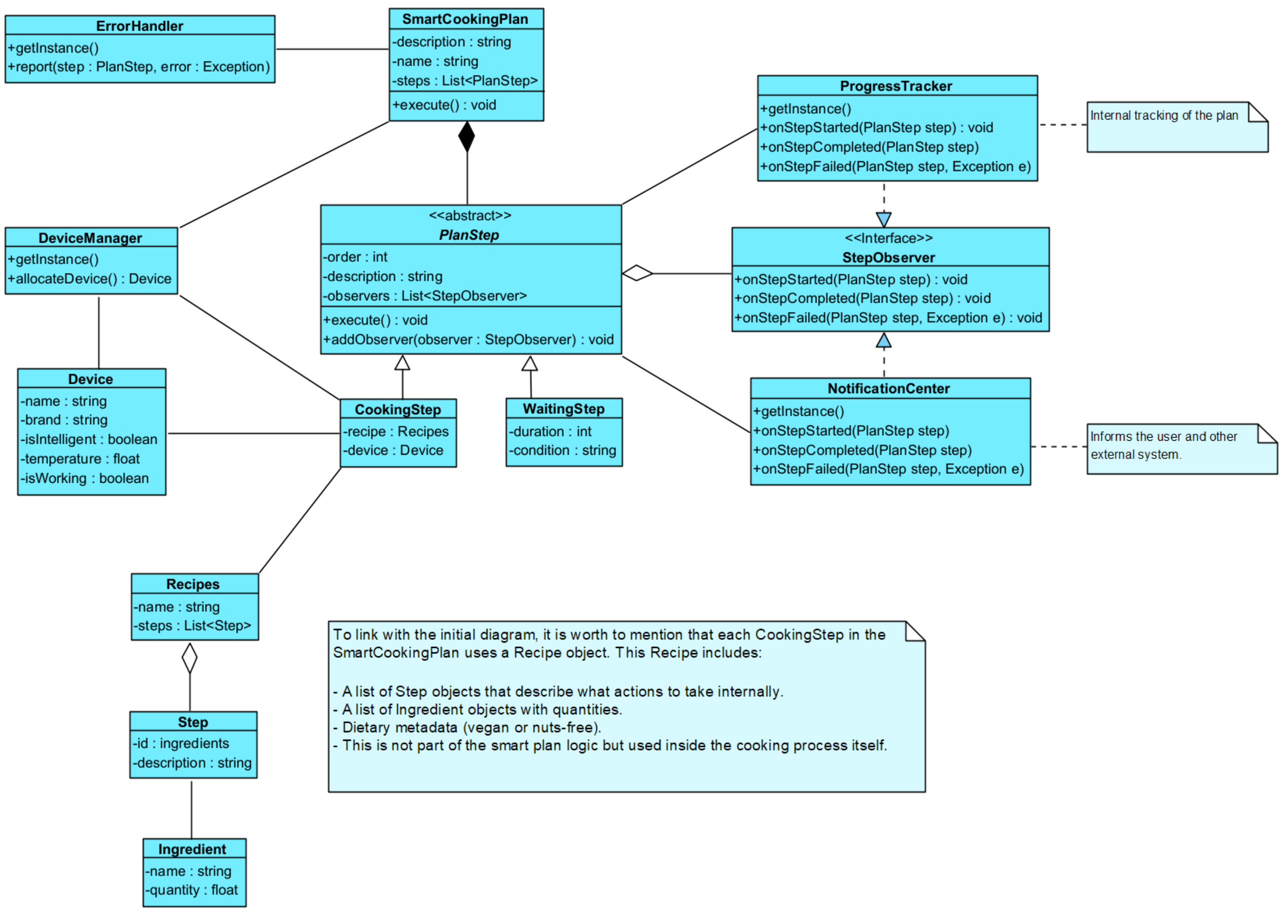
There are two main types of steps, the **CookingStep** that prepares and cooks a recipe using a smart device, and the **WaitingStep** that waits for a specific duration or condition before continuing.

In summary, I will design the core system with these main classes:

- **SmartCookingPlan**: a full plan with a list of cooking steps.
- **PlanStep**: a general type of step with common behavior.
- **CookingStep**: a step to cook a recipe using a device.
- **WaitingStep**: a step to wait (e.g., 30 minutes before next action).
- Support classes such as **NotificationCenter, ProgressTracker, DeviceManager**, etc.
- Initial diagram classes such as **Device, Recipe**, etc.

Each **SmartCookingPlan** is made of many steps. Each **step** is a type of **PlanStep**.

A possible class diagram implementation could be:



To link with the initial diagram, it is worth to mention that each CookingStep in the SmartCookingPlan uses a Recipe object. This Recipe includes:

- A list of Step objects that describe what actions to take internally.
- A list of Ingredient objects with quantities.
- Dietary metadata (vegan or nuts-free).
- This is not part of the smart plan logic but used inside the cooking process itself.

***Note**: This diagram includes only basic attributes, operations and relationships just for showing classes organization.*

2. Class functions and how they work together

1. **SmartCookingPlan** will run the full cooking process by calling **execute()** on each PlanStep.
2. Each step uses the template method to:
   a. Prepare the recipe and device.
   b. Notify to the system that the execution started.
   c. Run the main logic (cooking or waiting).
   d. Notify the completion and release the resources.
3. If a step fail, **SmartCookingPlan** will call a class named **ErrorHandler** to report the issue.
4. I will implement **NotificationCenter** and **ProgressTracker** classes to keep the user informed about the ongoing cooking process.
5. Finally, a **DeviceManager** class will be implemented to be used by **CookingStep** to request and assign the right smart device.

3. Patterns Used in this Design

In the proposed design, I will use **Template Method** as the main pattern, because I found it as a good option to manage the execution of cooking steps in a smart cooking plan. But I will also apply other patterns to organize the full system and make it easy to grow and maintain.

3.1 Template Method (main pattern)

The PlanStep class defines the general behaviour for running a step (**execute()**) and let the subclasses to define key parts of the process. This ensure that all the steps work consistently but with a custom logic.

3.2 Observer Pattern

The system helper classes like **NotificationCenter** and **ProgressTracker** notify other parts of the system when a step starts, completes or fails. The observers (user interfaces, alerts, etc.) will subscribe to be notified. **DeviceManager** may also implementing this pattern to be able to monitor the state of the devices (not represented in the class diagram).

3.3 Facade Pattern

The **SmartCookingPlan** class will act as a “facade" to simplify the interaction with this complex system. It will coordinate the execution, system management and progress tracking.

3.4 Singleton Pattern (supportive)

Classes like **DeviceManager**, **NotificationCenter**, **ProgressTracker** and **ErrorHandler** are used as singletons. This makes them easy to access from anywhere and ensures a centralized control of the shared responsibilities (represented in the diagram with the **getInstance()).**

4. Design Principles

As described in the statement, the design aims to cover other principles beyond the design patters. In the proposed design we can highlight:

4.1 High Cohesion

Each class is designed to have a clear role.

4.2 Low Coupling

Classes use helpers services (like device or manager trackers) without depending too much on their inner logic. The interaction is happening trough clean interfaces or singleton access.

4.3 Open/Closed Principle

The design is expected to make easy the creation of new types of steps without changing the base logic.

4.4 Shared logic is being centralized in the base class and reused by all the step types.

5. Conclusion

This proposed design is expected to be clean, modular and easy to maintain. I choose the Template Method as the main pattern to control how all cooking steps are executed, but used other patterns like Observer, Singleton and Facade to manage the communication and shared responsibilities. The system expects to cover the requirements of the statement for flexibility, scalability and the possibility to easily add more features in the future.

b) In this second task we need to extend the previous system functionality to be able to work with a Smart AI service. This service helps the user by changing recipes. For example, it can change a recipe to be vegan, gluten-free, etc.
To implement this, the statement describes two problems that need to be solved:

1. It cost money every time we call it.
2. Its recipe format is different from the one we use.

To solve these two problems, I will propose to use two design patterns that can work together:

Adapter Pattern

This pattern will help us to convert our recipe format into the format that the AI service needs. So, we don´t change our internal recipe class, we adapt it.

Proxy Pattern

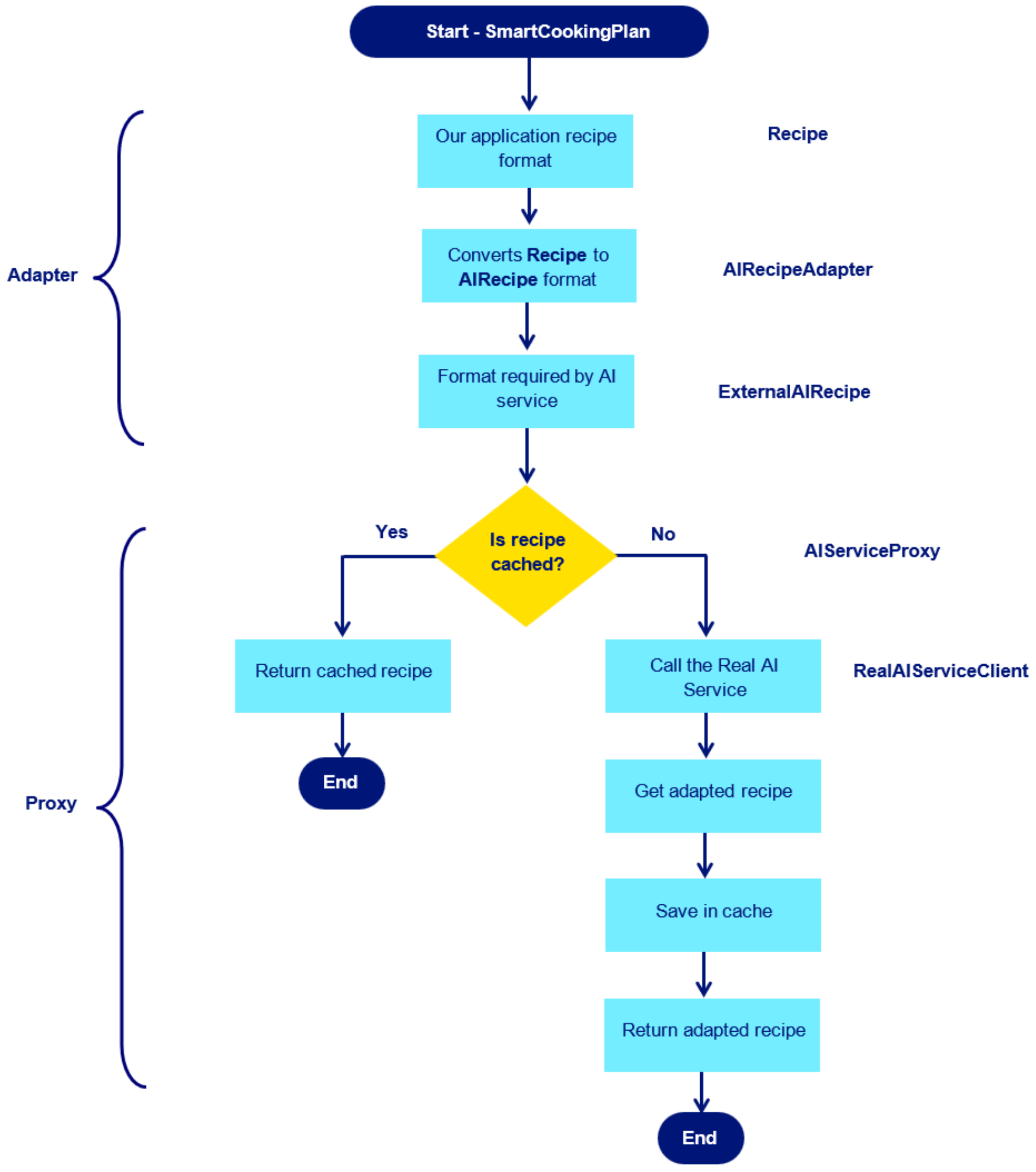
This pattern will help us to control access to the AI service. We will only call the AI if we really need it, but if we already have the answer, we will reuse it so we can save money avoiding calling the service

This two pattern together will make our system flexible, safe and efficient addressing the problems described in the statement.

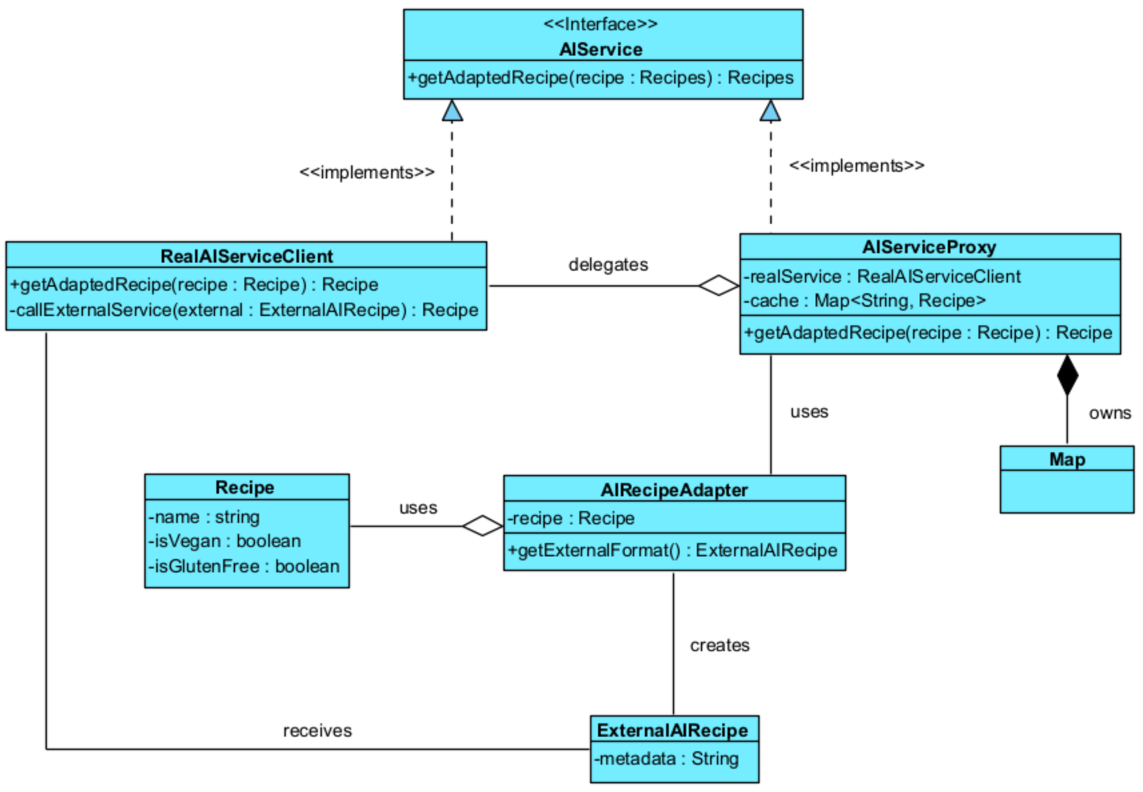
Conclusion:

Requirement	Chosen Pattern	Justification
Convert recipes to AI format	**Adapter Pattern**	Translates internal recipe to AI recipe
Avoid repeated AI calls	**Proxy Pattern**	Saves money by caching AI responses

A possible workflow for this service could be:



A very basic class organization for illustrating these patterns could be:


<<Interface>>
AIService
+getAdaptedRecipe(recipe : Recipes) : Recipes
<<implements>>
<<implements>>
RealAIServiceClient
+getAdaptedRecipe(recipe : Recipe) : Recipe
-callExternalService(external : ExternalAIRecipe) : Recipe
delegates
AIServiceProxy
-realService : RealAIServiceClient
-cache : Map<String, Recipe>
+getAdaptedRecipe(recipe : Recipe) : Recipe
uses
owns
Map
Recipe
-name : string
-isVegan : boolean
-isGlutenFree : boolean
uses
AIRecipeAdapter
-recipe : Recipe
+getExternalFormat() : ExternalAIRecipe
creates
receives
ExternalAIRecipe
-metadata : String

AIServiceProxy:
1. Gets a **Recipe** from the system.
2. Checks if the recipe is already in its cache.
3. If found in cache, returns it right away.
4. If not in cache:
    4.1 Creates an **AIRecipeAdapter** with that recipe.
    4.2 Calls adapter.getExternalFormat() to get an **ExternalAIRecipe**.
    4.3 Then calls realService.callExternalService(externalRecipe).
        RealAIServiceClient:
        4.3.1. Gets the ExternalAIRecipe as input.
        4.3.2. Makes the actual call to the external AI service.
        4.3.3. Returns an adapted Recipe with the informatio
    4.4 Saves the result in cache for next time.
5. Returns the recipe.