CSc 133 Lecture Notes

7 - Design Patterns (Part II)

Computer Science Department
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Announcement

- **Midterm exam is schedule on March 15.**
- **Allowed one page of note.**
- **Coverage: materials till end of this week.**

Overview

- **Background**
- **Types of Design Patterns**
  - **Creational vs. Structural vs. Behavioral Patterns**
- **Specific Patterns**

Composite	***Singleton***
Iterator	***Observer***
Strategy	***Command***
Proxy	***Factory Method***

- **MVC Architecture**

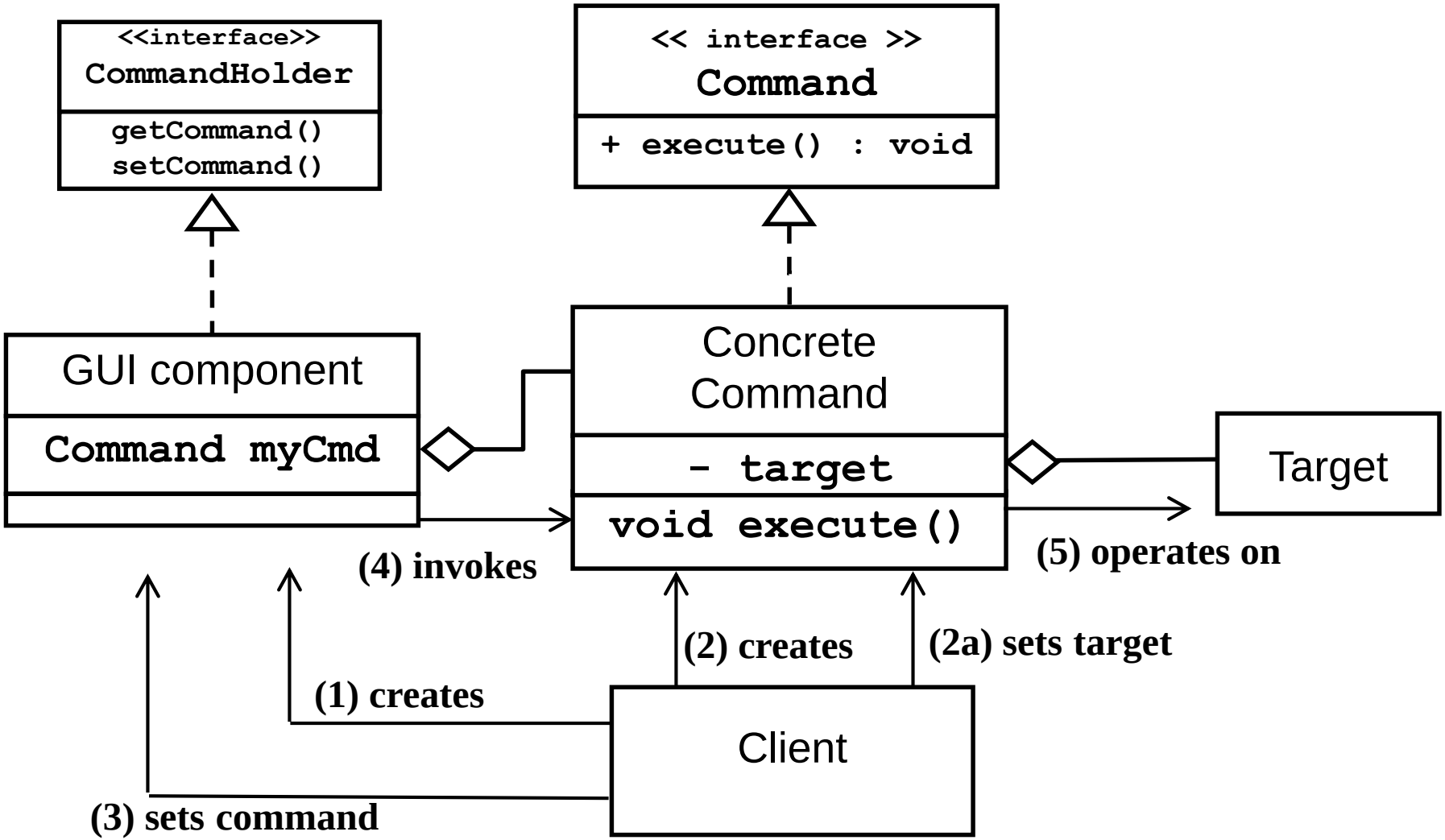
Part II – Design Pattern

The Command Pattern

Motivation

- Need to avoid having multiple copies of the code that performs the same operation invoked from different sources
- Desire to separate code implementing a command from the object which invokes it
- Need for maintaining *state information* about the command
  - Enabled or disabled?
  - Other data – e.g. invocation *count*

Command Pattern Organization



CN1 Command Class

- Implements **`ActionListener`** interface.
  - Provides empty body implementation for: **`actionPerformed()`** == "**`execute()`**"
  - We need to extend from **`Command`** and override **`actionPerformed()`** to perform the operation we would like to execute. In the constructor, do not forget to call super("command name")
- Also defines methods like: **`isEnabled(), setEnabled(), getCommandName()`**
- You can add a **command object** as a listener to a component using one of its **`addXXXListener()`** methods which takes **`ActionListener`** as a parameter (e.g. **`addPointerPressedListener()`** in **`Component`**, **`addActionListener()`** in **`Button`**, **`addKeyListener()`** in **`Form`**)
- When activated (button pushed, pointer/key pressed etc), component calls **`actionPerformed()`** method of its listener/command

CN1 `Command` Class (cont.)

Using the **`addKeyListener()`** of **`Form`**, we can attach a listener (an object of a listener class which implements **`ActionListener`** or an object of sub-class of **`Command`**) to a certain key.

This is called **key binding**: we are binding the listener/command (more specifically: the operation defined in its **`actionPerformed()`** method) to the key stroke, e.g:

```
/* Code for a form that uses key binding
//... [create a listener object called myCutCommand]
addKeyListener('c', myCutCommand);
//[when the 'c' key is hit, actionPerformed() method of CutCommand is called]
```

Summary of Implementing Command Design Pattern in CN1

- **Define your command classes:**
  - Extend **`Command`** (which implements **`ActionListener`** interface and provides empty body implementation of **`actionPerformed()`**)
  - Override **`actionPerformed()`**
- **Add a Toolbar and buttons to your form**
- **Instantiate command objects in your form**
- **Add command objects to various entities:**
  - (1) buttons w/ **`setCommand()`**, **`(2)`** title bar area items w/ **`Toolbar's addCommandToXXX()`** methods, **`(3)`** key strokes w/ **`Form`**'s **`addKeyListener()`**

Implementing Command Design Pattern in CN1

```
/** This class instantiates several command objects, creates several GUI
 * components (button, side menu item, title bar item), and attaches the command objects
 * to the GUI components and keys.  The command objects then automatically get invoked
 * when the GUI component or the key is activated.
 */

public class CommandPatternForm extends Form {
  public CommandPatternForm () {
    //...[set a Toolbar to form]
   Button buttonOne = new Button("Button One");
   Button buttonTwo = new Button("Button Two");
    //...[style and add two buttons to the form]
   //create command objects and set them to buttons, notice that labels of buttons
   //are set to command names
   CutCommand myCutCommand = new CutCommand();
   DeleteCommand myDeleteCommand = new DeleteCommand();
   buttonOne.setCommand(myCutCommand);
   buttonTwo.setCommand(myDeleteCommand);
    //add cut commnand to the right side of title bar area
   myToolbar.addCommandToRightBar(myCutCommand);
   //add delete command to the side menu
   myToolbar.addCommandToSideMenu(myDeleteCommand);
    //bind 'c' ket to cut command and 'd' key to delete command
   addKeyListener('c', myCutCommand);
   addKeyListener('d', myDeleteCommand);
   show();
   }
}
```

Implementing Command Design Pattern in CN1 (cont.)

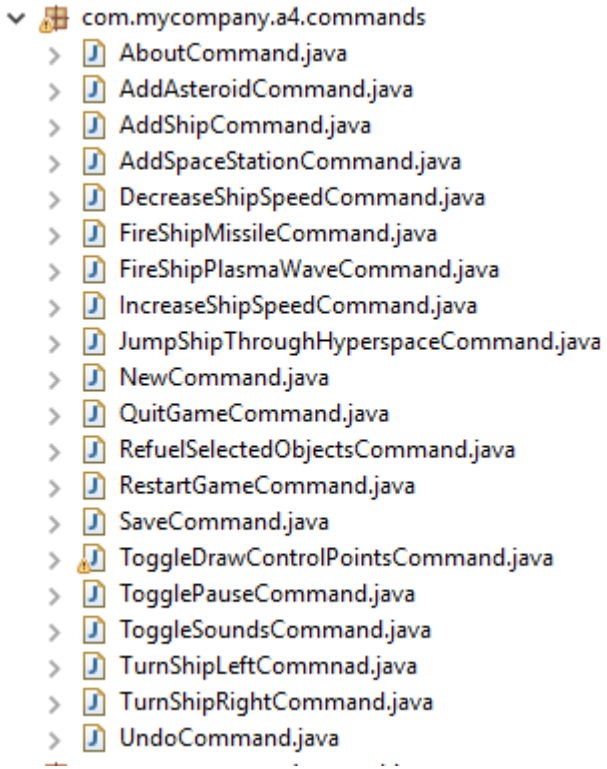
```
/** These classes define a Command which perform "cut" and "delete" operations.
 *  The commands are implemented as a subclass of Command, allowing it
 *  to be added to any object supporting attachment of Commands.
 *  This example does not show how the "Target" of the command is specified.
 */

public class CutCommand extends Command{
  public CutCommand() {
    super("Cut"); //do not forget to call parent constructor with command_name
  }
  @Override //do not forget @Override, makes sure you are overriding parent method
  //invoked to perform the 'cut' operation
  public void actionPerformed(ActionEvent ev){
    System.out.println("Cut command is invoked...");
  }
}
public class DeleteCommand extends Command{
  public DeleteCommand() {
    super("Delete");
  }
  @Override
  public void actionPerformed(ActionEvent e){
   System.out.println("Delete command is invoked...");
  }
}
```

Example: Command Design Pattern

```
6  public class AddAsteroidCommand extends Command {
7      //~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~//
8      //~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ F I E L D S ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~//
9      //~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~//
10
11     private GameWorld gw;   //Reference to a Game World
12     //~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~//
13     //~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ C O N S T R U C T O R S ~~~~~~~~~~~~~~~~~~~~~~~~//
14     //~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~//
15     /* There is only one constructor.
16      */
17     public AddAsteroidCommand( GameWorld gw ){
18         super( "Add Asteroid" );
19         this.gw = gw;
20     }
21     //~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~//
22     //~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ M E T H O D S ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~//
23     //~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~//
24     //There is only one method to override the action performed
25     @Override
26     public void actionPerformed( ActionEvent e ){
27         gw.addAsteroid();
28         System.out.println("Add Asteroid.");
29     }
30
31 }
```

(Note: assignment 1)

Organized commands in package for ease of accessment



The Strategy Pattern

Motivation

- A variety of algorithms exists to perform a particular operation
- The client needs to be able to select/change the choice of algorithm *at run-time.*

The Strategy Pattern (cont.)

Examples where different *strategies* might be used:

- Save a file in different formats (plain text, PDF, PostScript…)
- Compress a file using different compression algorithms
- Sort data using different sorting algorithms
- Capture video data using different encoding algorithms
- Plot the same data in different forms (bar graph, table, …)
- Have a game's non-player character (NPC) change its AI
- Arrange components in an on-screen window using different layout algorithms

Example: NPC AI Algorithms

Typical client code sequence:

```
void attack() {

        switch (characterType) {
        case WARRIOR:   fight();                break;
        case HUNTER:    fireWeapon();           break;
        case PRIEST:    castDisablingSpell();   break;
        case SHAMAN:    castMagicSpell();       break;
        }
}
```

Problem with this approach?

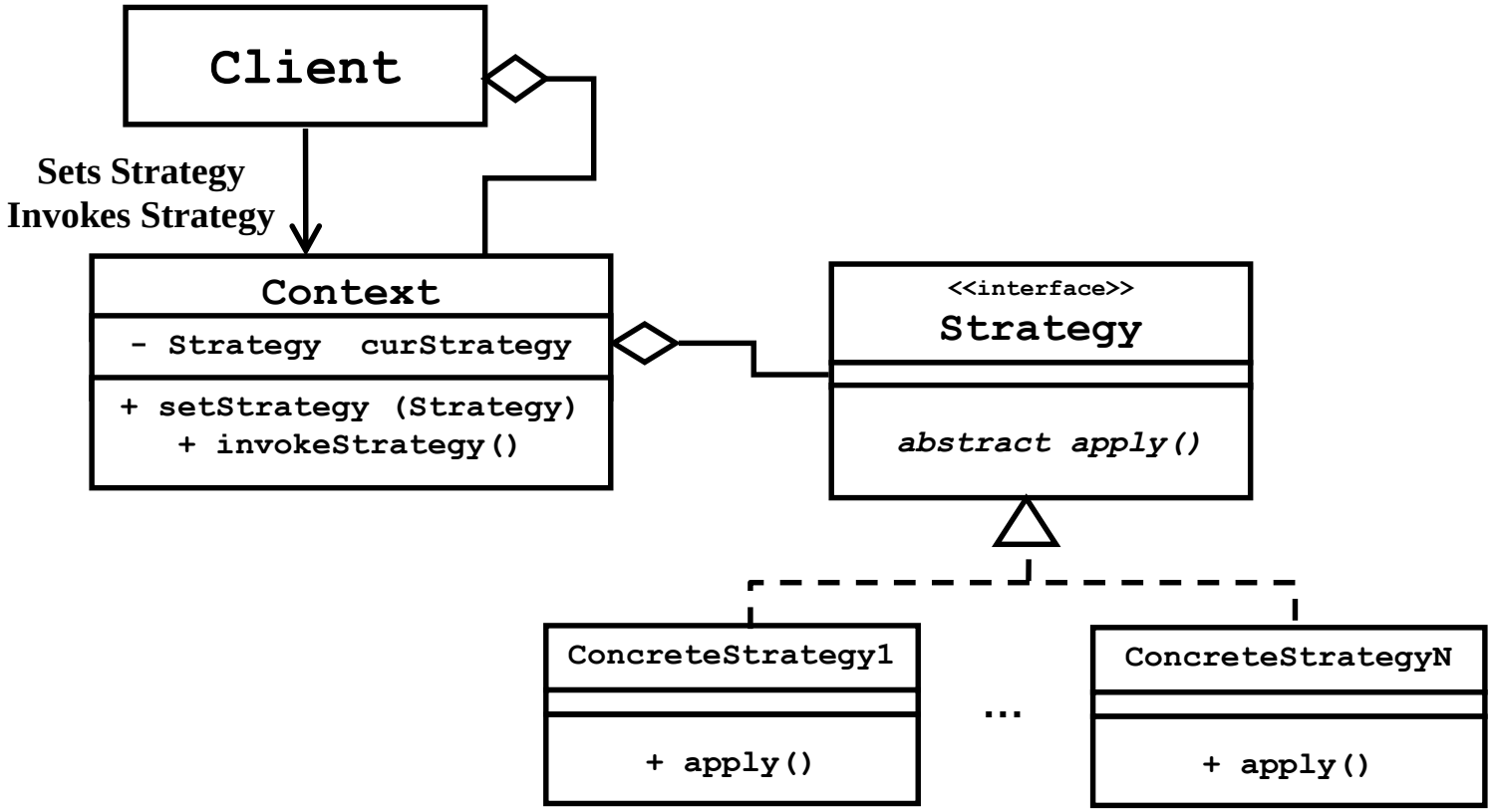
Changing or adding a plan requires changing the client!

Solution Approach

- Provide various objects that know how to "apply strategy" (e.g. apply fight, fireWeapon, or castMagicSpell strategies)
  - Each in a different way, but with a uniform interface
- The context (e.g. NPC) maintains a "current strategy" object
- Provide a mechanism for the client (e.g. Game) to *change* and *invoke* the current strategy object of a context

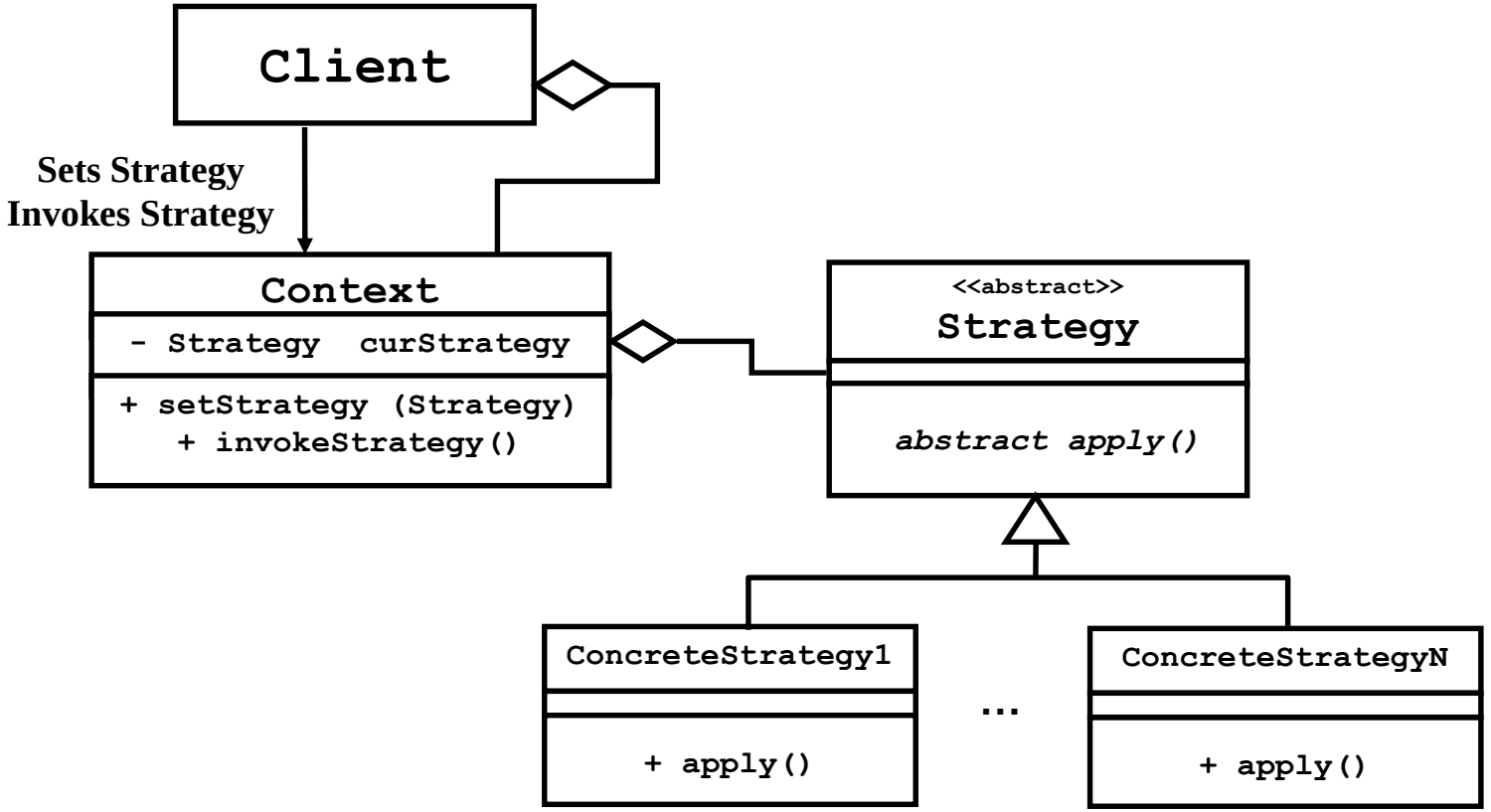
Strategy Pattern Organization

- **Using Interfaces**

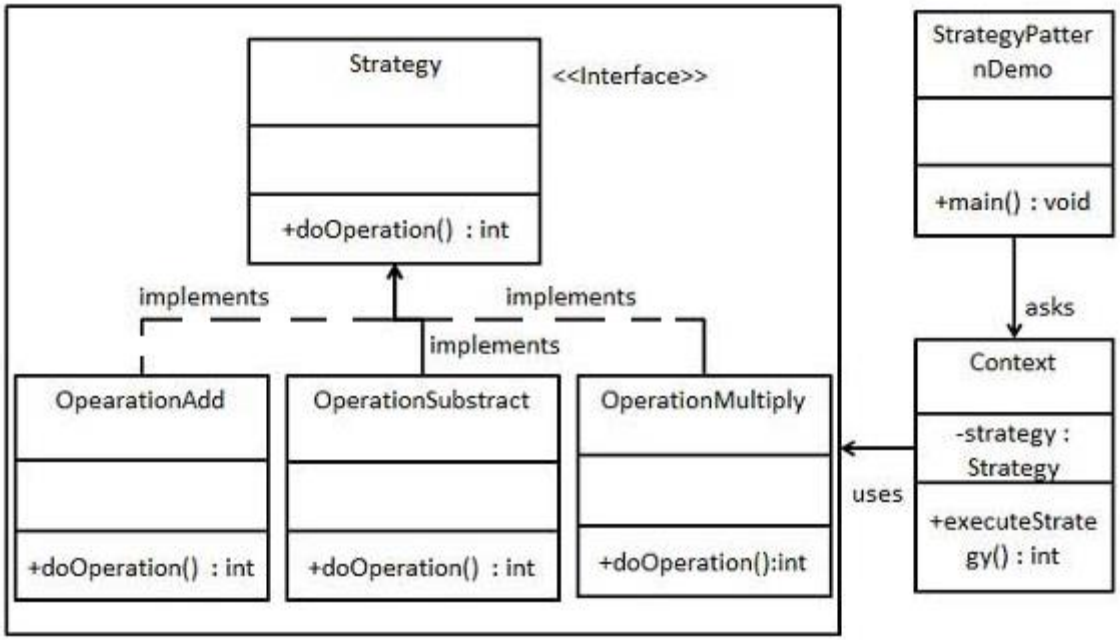


Strategy Pattern Organization (cont.)

- **Using subclassing**



Example: StrategyPatternDemo (Using Interface)



StrategyPatternDemo will use Context and strategy objects to demonstrate change in Context behavior based on strategy it deploys or uses.

Source: https://www.tutorialspoint.com/design_pattern/strategy_pattern.htm

Example: StrategyPatternDemo (Cont)

Step 1: Create an interface

```
public interface Strategy {
   public int doOperation(int
num1, int num2);
}
```

Step 2: Create concrete classes implementing the same interface.

```
public class OperationAdd implements Strategy{
   @Override
   public int doOperation(int num1, int num2) {
      return num1 + num2;
   }
}

public class OperationSubstract implements
Strategy{
   @Override
   public int doOperation(int num1, int num2) {
      return num1 - num2;
   }
}

public class OperationMultiply implements
Strategy{
   @Override
   public int doOperation(int num1, int num2) {
      return num1 * num2;
   }
}
```

Example: StrategyPatternDemo (Cont)

Step 3: Create context class

```
public class Context {
   private Strategy strategy;

   public Context(Strategy
strategy){
      this.strategy = strategy;
   }

   public int executeStrategy(int
num1, int num2){
      return
strategy.doOperation(num1, num2);
   }
}
```

Step 5: Verify result:

```
10 + 5 = 15
10 - 5 = 5
10 * 5 = 50
```

Step 4: Use the Context to see change in behavior when it changes its Strategy..

```
public class StrategyPatternDemo {
   public static void main(String[] args) {
      Context context = new Context(new OperationAdd());

      System.out.println("10 + 5 = " +
context.executeStrategy(10, 5));

      context = new Context(new OperationSubstract());
      System.out.println("10 - 5 = " +
context.executeStrategy(10, 5));

      context = new Context(new OperationMultiply());
      System.out.println("10 * 5 = " +
context.executeStrategy(10, 5));
   }
}
```

Example: CN1 Layouts

- Strategy abstract super class:

  `Layout`

- Client is the **`Form`**
- Context: **`Container`** (e.g., **`ContentPane`** of **`Form`**)
- Context methods:

```
public void setLayout (Layout lout)
public void revalidate()
```

- Concrete strategies (**`extends Layout`**):

```
class FlowLayout()
class BorderLayout()
class GridLayout()
...
```

- "Apply" method (declared in the **`Layout`** super class):

  abstract **`void layoutContainer(Container parent)`**

Example: NPC's in a Game

```
public interface Strategy {
    public void apply();
}

public class FightStrategy implements Strategy {
    public void apply() {
        //code here to do "fighting"
    }
}

public class FireWeaponStrategy implements Strategy {
    private Hunter hunter;
    public FireWeaponStrategy(Hunter h) {
        this.hunter = h;   //record the hunter to which this strategy applies
    }
    public void apply() {
        //tell the hunter to fire a burst of 10 shots
        for (int i=0; i<10; i++) {
            hunter.fireWeapon();
        }
    }
}

public class CastMagicSpellStrategy implements Strategy {
    public void apply() {
        //code here to cast a magic spell
    }
}
```

NPC's in a Game (cont.)

"Contexts" :

```
public class Character {
    private Strategy curStrategy;
    public void setStrategy(Strategy s) {
        curStrategy = s;
    }
    public void invokeStrategy() {
        curStrategy.apply();
    }
}
```

```
public class Warrior extends Character {

//code here for Warrior specific methods

}
```

```
public class Shaman extends Character {

//code here for Shaman specific methods

}
```

```
public class Hunter extends Character {
    private int bulletCount ;

    public boolean isOutOfAmmo() {
        if (bulletCount <= 0) return true;
        else return false;
    }
    public void fireWeapon() {
        bulletCount -- ;
    }

//code here for other Hunter specific
//methods

}
```

Assigning / Changing Strategies

```
/** This Game class demonstrates the use of the Strategy Design Pattern
 *  by assigning attack response strategies to each of several game characters.
 */
public class Game {
    //the list of non-player characters in the game
    ArrayList<Character> npcList = new ArrayList<Character>();
    public Game() {    //construct some characters, assigning each a starting strategy
        Warrior w1 = new Warrior();
        w1.setStrategy(new FightStrategy());
        npcList.add(w1);
        Hunter h1 = new Hunter();
        h1.setStrategy(new FireWeaponStrategy(h1));
        npcList.add(h1);
        Shaman s1 = new Shaman();
        s1.setStrategy(new CastSpellStrategy());
        npcList.add(s1);
    }
    public void attack() {    //force each character to execute its attack response
        for (Character c : npcList) {
            c.invokeStrategy();
        }
    }
    public void updateCharacters() {  //update any strategies that need changing
        for (Character c : npcList) {
            if(c instanceof Hunter) {
                if ( ((Hunter)c).isOutOfAmmo() ) {
                    //change the character's strategy
                    c.setStrategy(new FightStrategy());
                }
            }
        }
    }
}
```

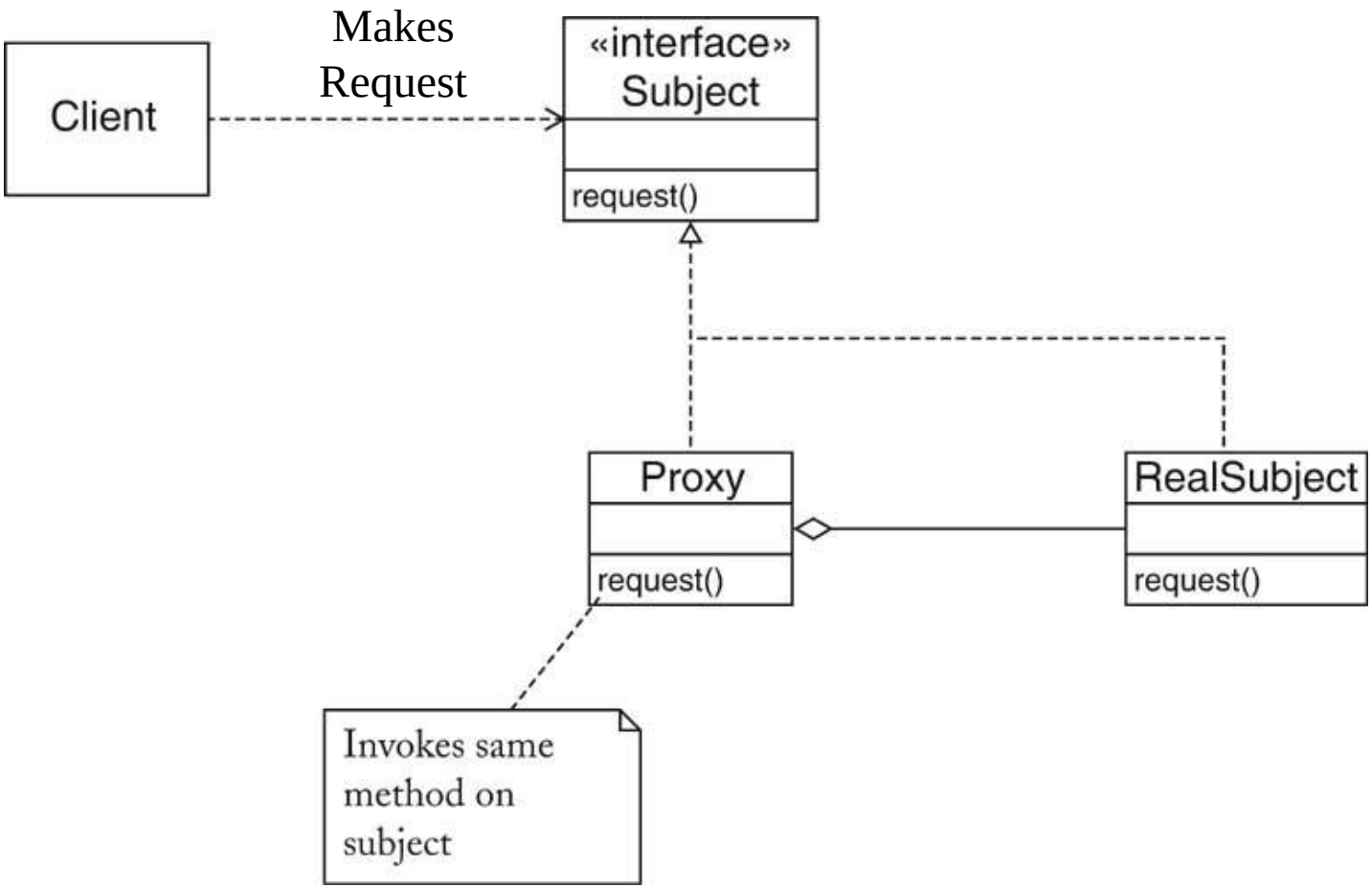
The Proxy Pattern

- Motivation
  - Undesirable target object manipulation
    - Access required, but not to all operations
  - Expensive target object manipulation
    - Lengthy image load time
    - Significant object creation time
    - Large object size
  - Inaccessible target object
    - Resides in a different address space
      - E.g. another JVM or a machine on a network

Proxy Types

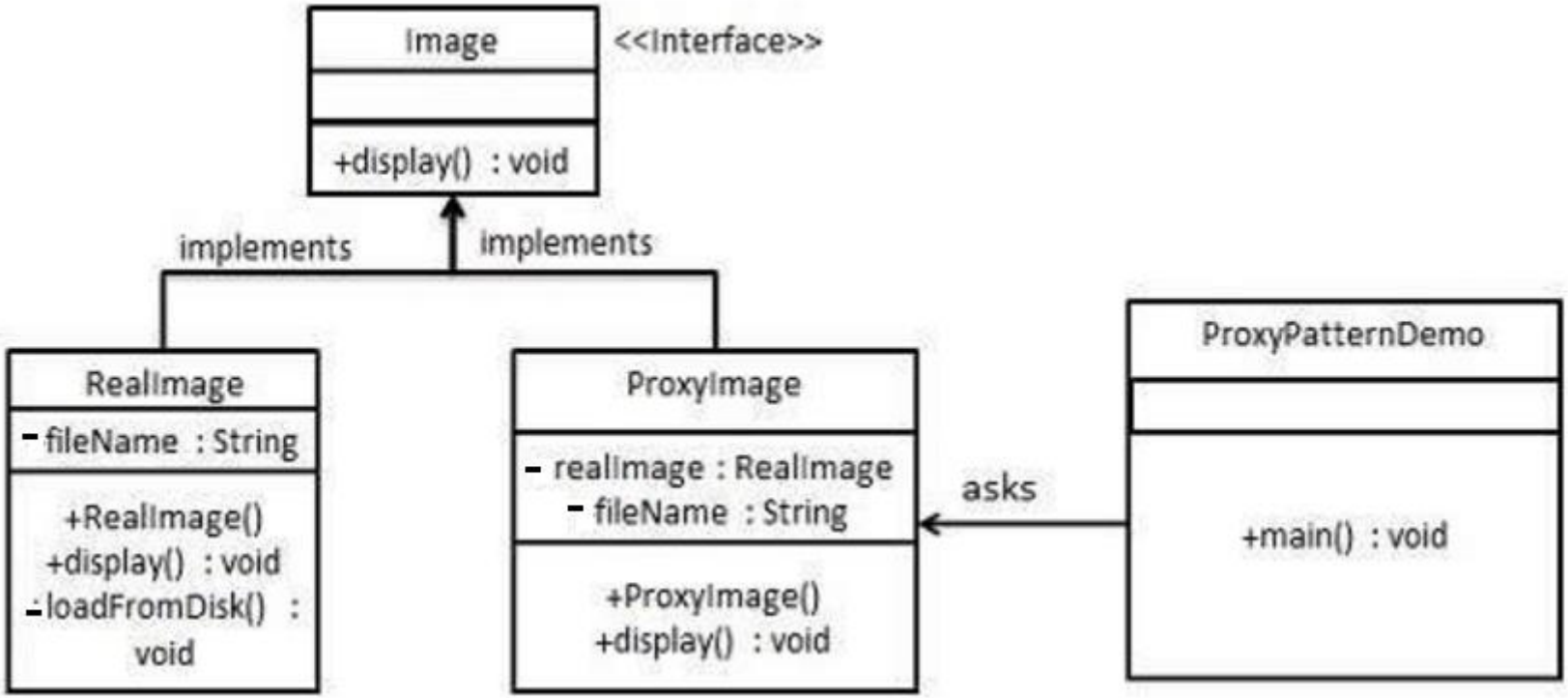
- **Protection Proxy – controls access**
- **Virtual Proxy – acts as a stand-in**
- **Remote Proxy – local stand-in for object in another address space**
- **This type of design pattern comes under structural pattern.**

Proxy Pattern Organization



Proxy Example 1

ProxyImage is a proxy class to reduce memory footprint of RealImage object loading. ProxyPatternDemo, our demo class, will use ProxyImage to get an Image object to load and display as it needs.

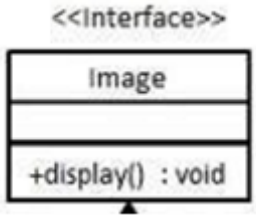


Source: https://www.tutorialspoint.com/design_pattern/proxy_pattern.htm

Proxy Example 1 (Cont)

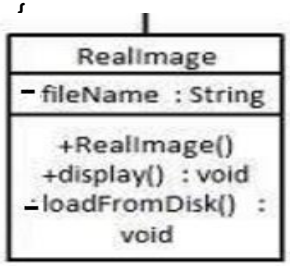
Step 1: Create an interface

```
public interface Image {
   void display();
}
```



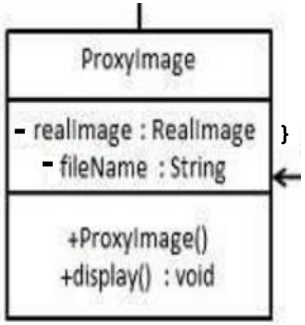
Step 2: Create concrete classes implementing the same interface.

```
public class RealImage implements Image {

   private String fileName;

   public RealImage(String fileName){
      this.fileName = fileName;
      loadFromDisk(fileName);
   }

   @Override
   public void display() {
      System.out.println("Displaying " + fileName);
   }

   private void loadFromDisk(String fileName){
      System.out.println("Loading " + fileName);
   }
```



Step 2: Create concrete classes implementing the same interface.

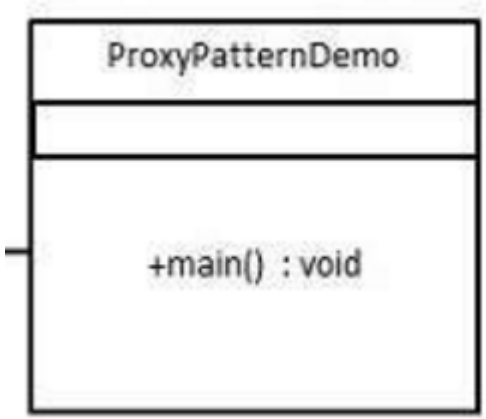
```
public class ProxyImage implements Image{

   private RealImage realImage;
   private String fileName;

   public ProxyImage(String fileName){
      this.fileName = fileName;
   }

   @Override
   public void display() {
      if(realImage == null){
         realImage = new RealImage(fileName);
      }
      realImage.display();
   }
}
```



Proxy Example 1 (Cont)

Step 3: Use the ProxyImage to get object of RealImage class when required..

```
public class ProxyPatternDemo {

   public static void main(String[] args) {
      Image image = new ProxyImage("test_10mb.jpg");

      //image will be loaded from disk
      image.display();
      System.out.println("");

      //image will not be loaded from disk
      image.display();
   }
}
```



Step 4: Verify result.

```
Loading test_10mb.jpg
Displaying test_10mb.jpg

Displaying test_10mb.jpg
```

Proxy Example 2

```
interface IGameWorld {
     Iterator getIterator();
     void addGameObject(GameObject o);
     boolean removeGameObject (GameObject o);
}


/**A proxy which prohibits removal of GameWorldObjects from the GameWorld*/
public class GameWorldProxy implements IObservable, IGameWorld {
     private GameWorld realGameWorld ;
     public GameWorldProxy (GameWorld gw)
       { realGameWorld = gw; }
     public Iterator getIterator ()
       { return realGameWorld.getIterator(); }
     public void addGameObject(GameObject o)
       {  realGameWorld.addGameObject(o) ;  }
     public boolean removeGameObject (GameObject o)
       {  return false ; }
     //...[also has methods implementing IObservable]
}
```

Proxy Example 2 (cont.)

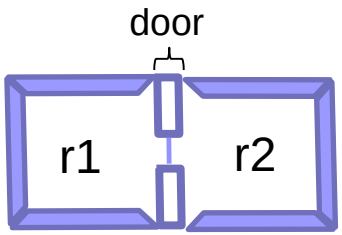
```
/** This class defines a Game containing a GameWorld with a ScoreView Observer. */
public class Game {
    public Game() {
        GameWorld gw = new GameWorld();   //construct a GameWorld
        ScoreView sv = new ScoreView();   //construct a ScoreView
        gw.addObserver(sv);               //register ScoreView as a GameWorld Observer
    }
}
--------------------------------------------------------------------------------
/** This class defines a GameWorld which is an Observable and maintains a list of
 *  Observers; when the GameWorld needs to notify its Observers of changes it does so
 *  by passing a GameWorldProxy to the Observers. */
public class GameWorld implements IObservable, IGameWorld {
    private Vector<GameObject> myGameObjectList = new Vector<GameObject>();
    private Vector<IObserver> myObserverList = new Vector<IObserver>();
    public Iterator<GameObject> getIterator() { ... }
    public void addGameObject(GameObject o) { ... }
    public boolean removeGameObject(GameObject o) {
        //code here to remove the specified GameObject from the GameWorld...
    }
    public void addObserver(IObserver o) { myObserverList.add(o); }

    //Pass a GameWorldProxy to Observers, thus prohibiting Observer removal of GameObjects
    public void notifyObservers() {
        GameWorldProxy proxy = new GameWorldProxy(this);
        for (IObserver o : myObserverList) {
            o.update((IObservable)proxy, null);
        }
    }
}
```

The Factory Method Pattern

- **Motivation**
  - **We create object without exposing the creation logic to the client and refer to newly created object using a common interface.**
  - **Sometimes a class can't anticipate the class of objects it must create**
  - **It is sometimes better to delegate specification of object types to subclasses**
  - **It is frequently desirable to avoid binding application-specific classes into a set of code**

Example: Maze Game

```
public class MazeGame {

    // This method creates a maze for the game, using a hard-coded structure for the
    // maze (specifically, it constructs a maze with two rooms connected by a door).
    public Maze createMaze () {

        Maze theMaze = new Maze() ;   //construct an (empty) maze

        Room r1 = new Room(1) ;       //construct components for the maze
        Room r2 = new Room(2) ;
        Door theDoor = new Door(r1, r2);

        r1.setSide(NORTH, new Wall()); //set wall properties for the rooms
        r1.setSide(EAST,  theDoor);
        r1.setSide(SOUTH, new Wall());
        r1.setSide(WEST,  new Wall());

        r2.setSide(NORTH, new Wall());
        r2.setSide(EAST,  new Wall());
        r2.setSide(SOUTH, new Wall());
        r2.setSide(WEST,  theDoor);

        theMaze.addRoom(r1); //add the rooms to the maze
        theMaze.addRoom(r2);

        return theMaze ;
    }

    //other MazeGame methods here (e.g. a main program which calls createMaze())...
}
```



Based on an example in "*Design Patterns: Elements of Reusable Object-Oriented Software*" by Gamma et. al. (the so-called "Gang of Four" book).

Problems with `createMaze()`

- Inflexibility; lack of "reusability"
- Reason: it "hardcodes" the maze types
  - Suppose we want to create a maze with (e.g.)
    - Magic Doors
    - Enchanted Rooms
  - Possible solutions:
    - Subclass MazeGame and override **`createMaze()`** (i.e., create a whole new version with new types)
    - Hack **`createMaze()`** apart, changing pieces as needed

createMaze() Factory Methods

```
public class MazeGame {

    //factory methods - each returns a MazeComponent of a given type
    public Maze makeMaze()         { return new Maze() ; }
    public Room makeRoom(int id)   { return new Room(id) ; }
    public Wall makeWall()         { return new Wall() ; }
    public Door makeDoor(Room r1, Room r2) { return new Door(r1,r2) ; }

    // Create a maze for the game using factory methods
    public Maze createMaze () {
        Maze theMaze = makeMaze() ;
        Room r1 = makeRoom(1) ;
        Room r2 = makeRoom(2) ;
        Door theDoor = makeDoor(r1, r2);
        r1.setSide(NORTH, makeWall());
        r1.setSide(EAST,  theDoor);
        r1.setSide(SOUTH, makeWall());
        r1.setSide(WEST,  makeWall());
        r2.setSide(NORTH, makeWall());
        r2.setSide(EAST,  makeWall());
        r2.setSide(SOUTH, makeWall());
        r2.setSide(WEST,  theDoor);
        theMaze.addRoom(r1);
        theMaze.addRoom(r2);
        return theMaze ;
    }
    ...
}
```

Overriding Factory Methods

```
//This class shows how to implement a maze made of different types of rooms.  Note
// in particular that we can call exactly the same (inherited) createMaze() method
// to obtain a new "EnchantedMaze".
public class EnchantedMazeGame extends MazeGame {

    //override MakeRoom to produce "EnchantedRooms"
    @Override
    public Room makeRoom(int id) {

        //create the spell necessary to enter the enchanted room
        Spell spell = makeSpell() ;

        //construct and return an EnchantedRoom requiring a spell to be entered
        return new EnchantedRoom(id, spell);
    }

    //override MakeDoor to produce a door requiring a spell
    @Override
    public Door makeDoor(Room r1, Room r2) {

        //construct and return a Door requiring a spell to be entered
        return new DoorNeedingSpell(r1, r2);
    }

    //new factory method for making spells
    public Spell makeSpell() { return new Spell() ;}
    ...
}
```