Command

CSCI 4448/5448: Object-Oriented Analysis & Design

Lecture 17

Acknowledgement & Materials Copyright

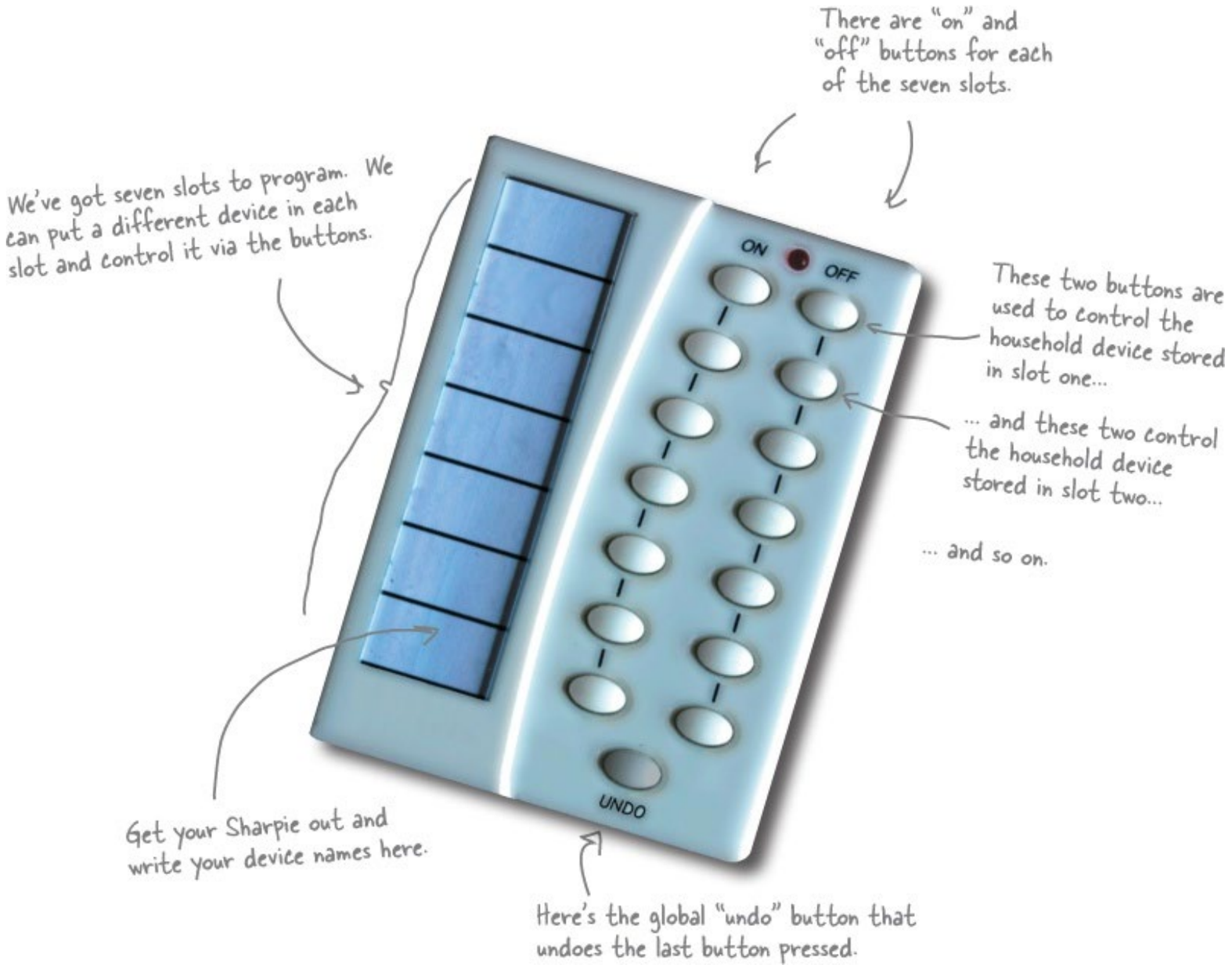
- I'd like to start by acknowledging Dr. Ken Anderson
- Ken is a Professor and the Chair of the Department of Computer Science
- Ken taught OOAD on several occasions, and has graciously allowed me to use his copyrighted material for this instance of the class
- Although I will modify the materials to update and personalize this class, the original materials this class is based on are all copyrighted © Kenneth M. Anderson; the materials are used with his consent; and this use in no way challenges his copyright

Command Pattern

- Today's discussion on Command is largely from Chapter 6 of the Head First Design Patterns book
  - Read through it when you can for more details…

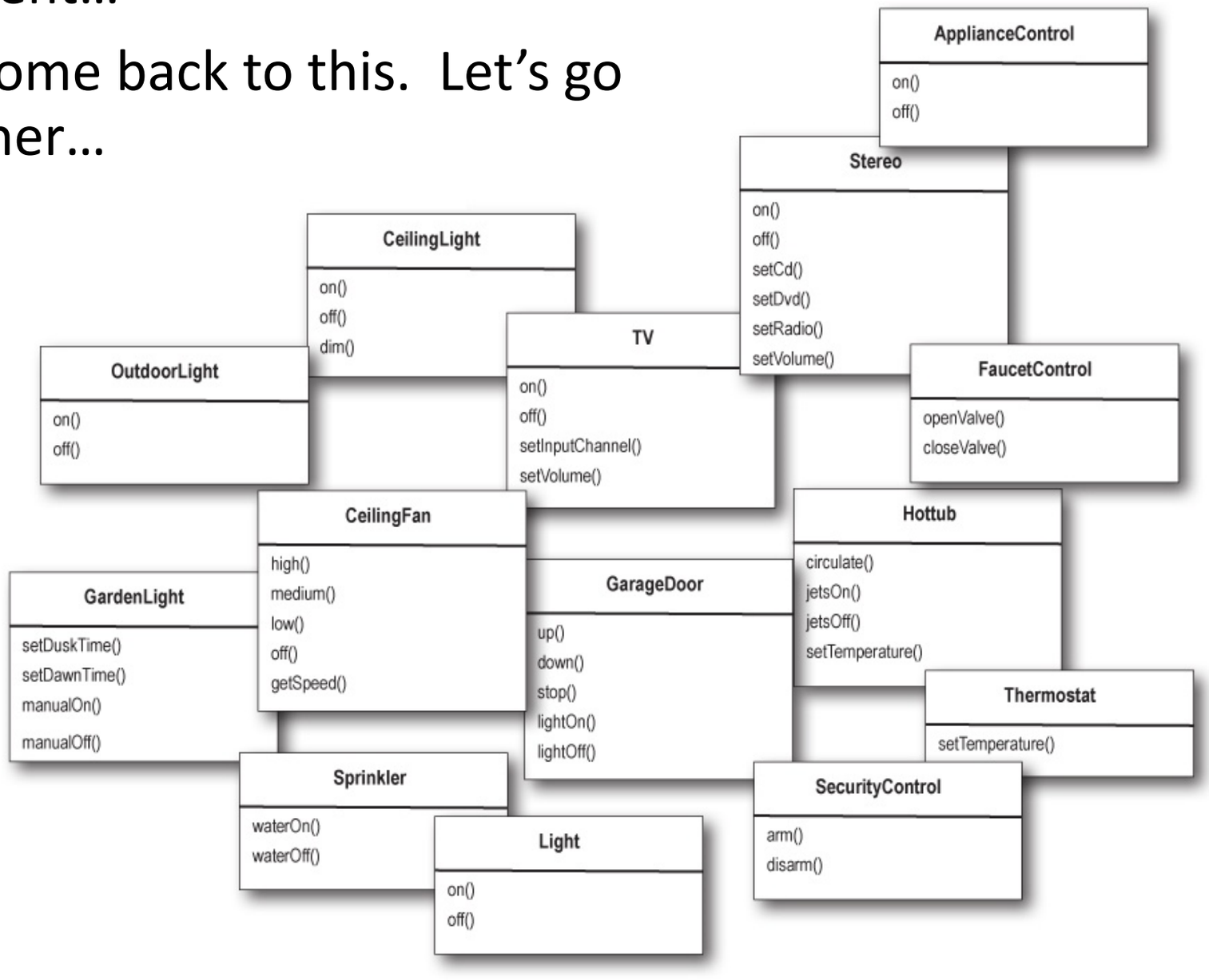
The Problem – A Remote Control

- The book presents a remote control with 7 programmable slots, each with an on and off button, plus a global undo button



The Other Problem – Many Different Devices

- The book presents a set of classes for the different commands each device controlled by the remote can respond to, and they're not consistent…
- We'll come back to this. Let's go to a diner…



The Diner

- Customer -> Order -> Waitress -> Order Slip
- Waitress -> Order Slip -> Order Counter
- Cook -> gets Order Slip -> makes Order

The Command Pattern is Here!

- Customer -> Order -> Waitress -> Order Slip
- Waitress -> Order Slip -> Order Counter
- Cook -> gets Order Slip -> makes Order

- Customer is a **Client**, needs this action, an Order, to be executed
- Order Slip – Encapsulates a Request – a **Request** object
  - It has one method – OrderUp() – containing the actions needed to prepare the Order
  - In fact, the Waitress does not need to know what's in the Order or who prepares the Order, they just have to deliver, or invoke, the request
- The Waitress is the **Invoker**
  - The Cook doesn't really care who asked for the Order, they just need to see an Order has arrived and act on it per the Order Slip
- The Cook is the **Receiver** – they do the action outlined in the request

Command Pattern

- Start at Client
- **Client** Object – CreateCommandObject() - a Request
  - Command_Object knows
    - Who is the target Receiver
    - What actions do I need the Receiver to execute? (Receiver methods)
- **Command**_Object – defines Execute()
  - Command.Execute() will be called to invoke specified Receiver actions
- Client Object - Invoker.SetCommand(Command_Object)
  - Client tells Invoker I have a Command_Object for you
- **Invoker** – Command_Object.Execute()
  - The Invoker calls Command_Object.Execute()…
  - What the timing is of executing that command may vary
- **Receiver** – executes the Receiver actions in the Command_Object when the Invoker says to

Implementing a Command Interface and a Command

```
public interface Command {
        public void execute();
}

public class LightOnCommand implements Command {
        Light light;  //reference to the command Receiver

        // constructor – sets the specific light to command
        public LightOnCommand(Light light) {
                this.light = light;
        }

        // override for execute with specifically what action the light needs to do
        public void execute() {
                light.on();
        }
}
```

Using the Command Object

- If we had a remote control with one button, we could have it hold a command and control a device. The remote is the Invoker:

```
public class SimpleRemoteControl {
        Command slot;
        public SimpleRemoteControl() { }

        public void setCommand(Command command) {
                slot = command;
        }

        public void ButtonPressed() {
                slot.execute();
        }
}
```

Testing a Command

This is our Client in Command Pattern–speak.

The remote is our Invoker; it will be passed a command object that can be used to make requests.

```
public class RemoteControlTest {
    public static void main(String[] args) {
        SimpleRemoteControl remote = new SimpleRemoteControl();
        Light light = new Light();
        LightOnCommand lightOn = new LightOnCommand(light);
        remote.setCommand(lightOn);
        remote.buttonWasPressed();
    }
}
```

Now we create a Light object. This will be the Receiver of the request.

Here, create a command and pass the Receiver to it.

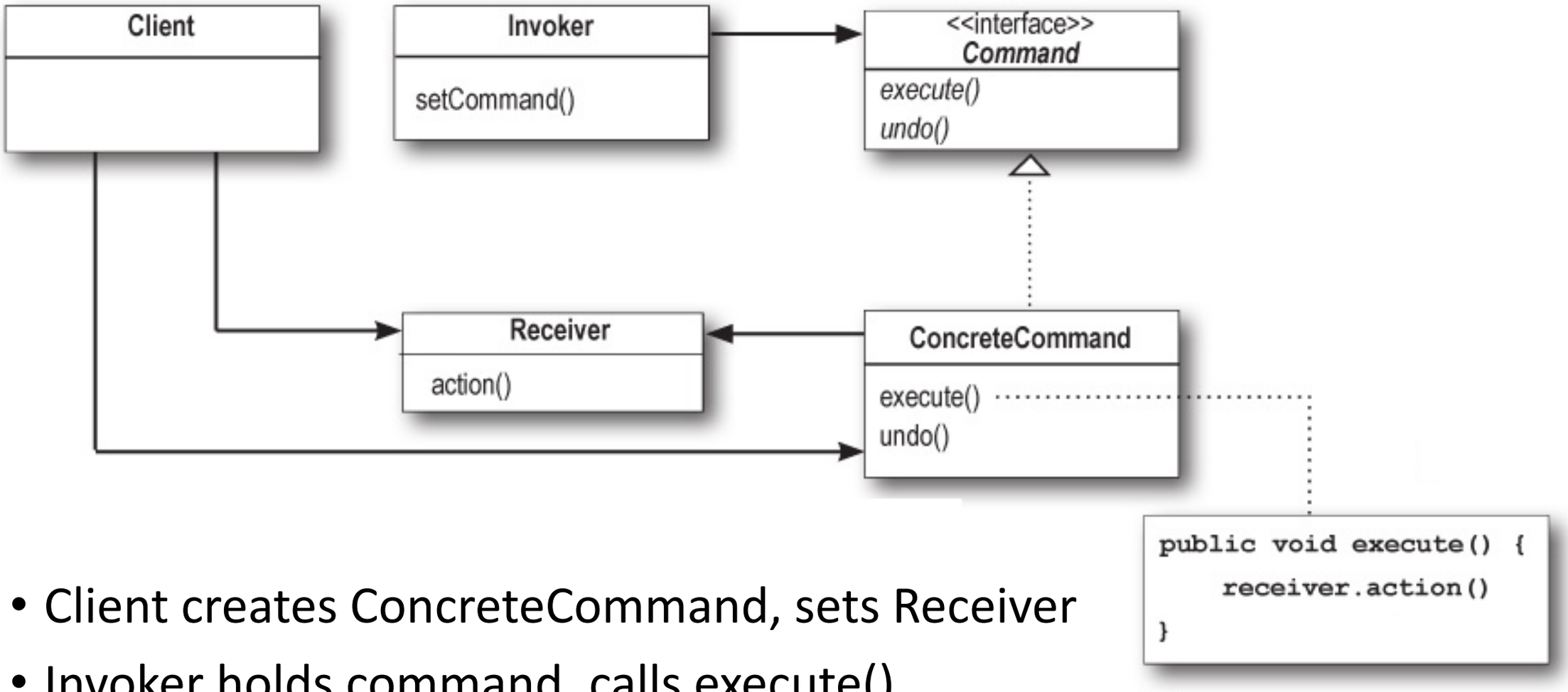
Here, pass the command to the Invoker.

And then we simulate the button being pressed.

Here's the output of running this test code.

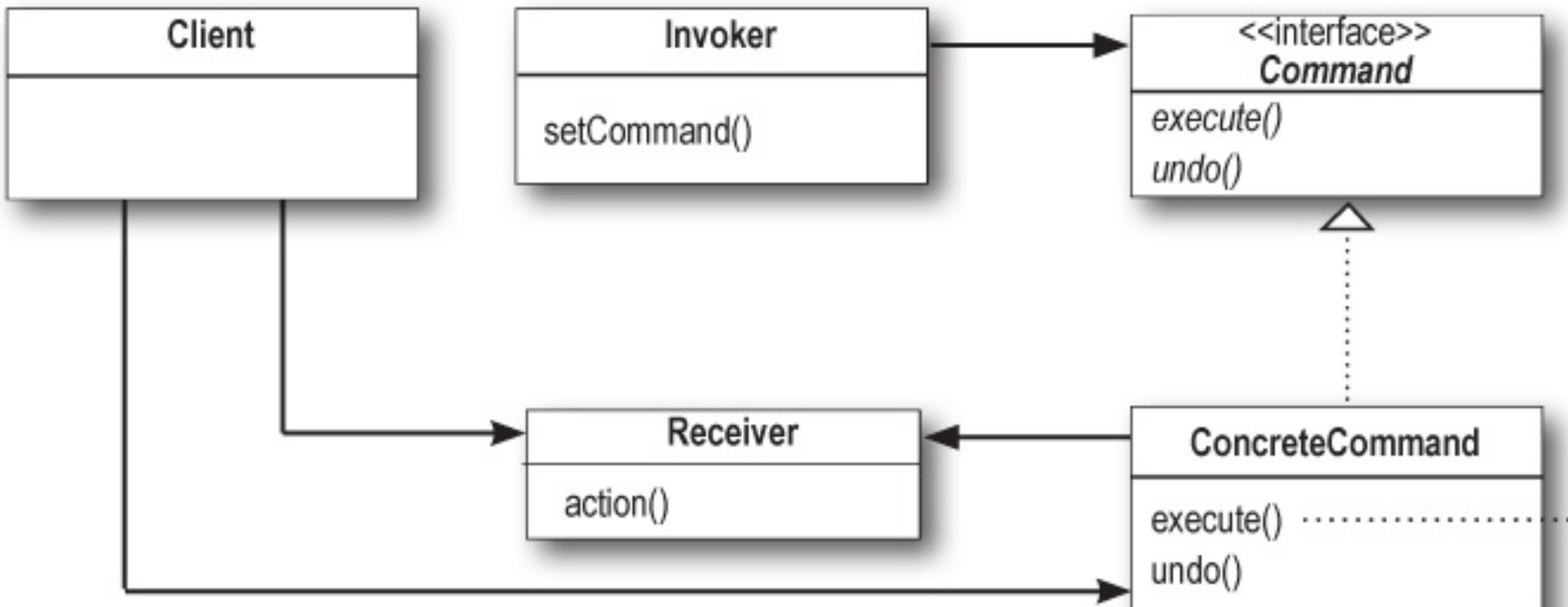
```
File  Edit  Window  Help  DinerFoodYum
%java RemoteControlTest

Light is On

%
```

UML for Command Pattern



- Client creates ConcreteCommand, sets Receiver
- Invoker holds command, calls execute()
- Command interface specifies common command methods
- ConcreteCommand is the binding between Receivers and actions
- Receiver provide actions to execute (any class can be a Receiver)

UML for Command Pattern

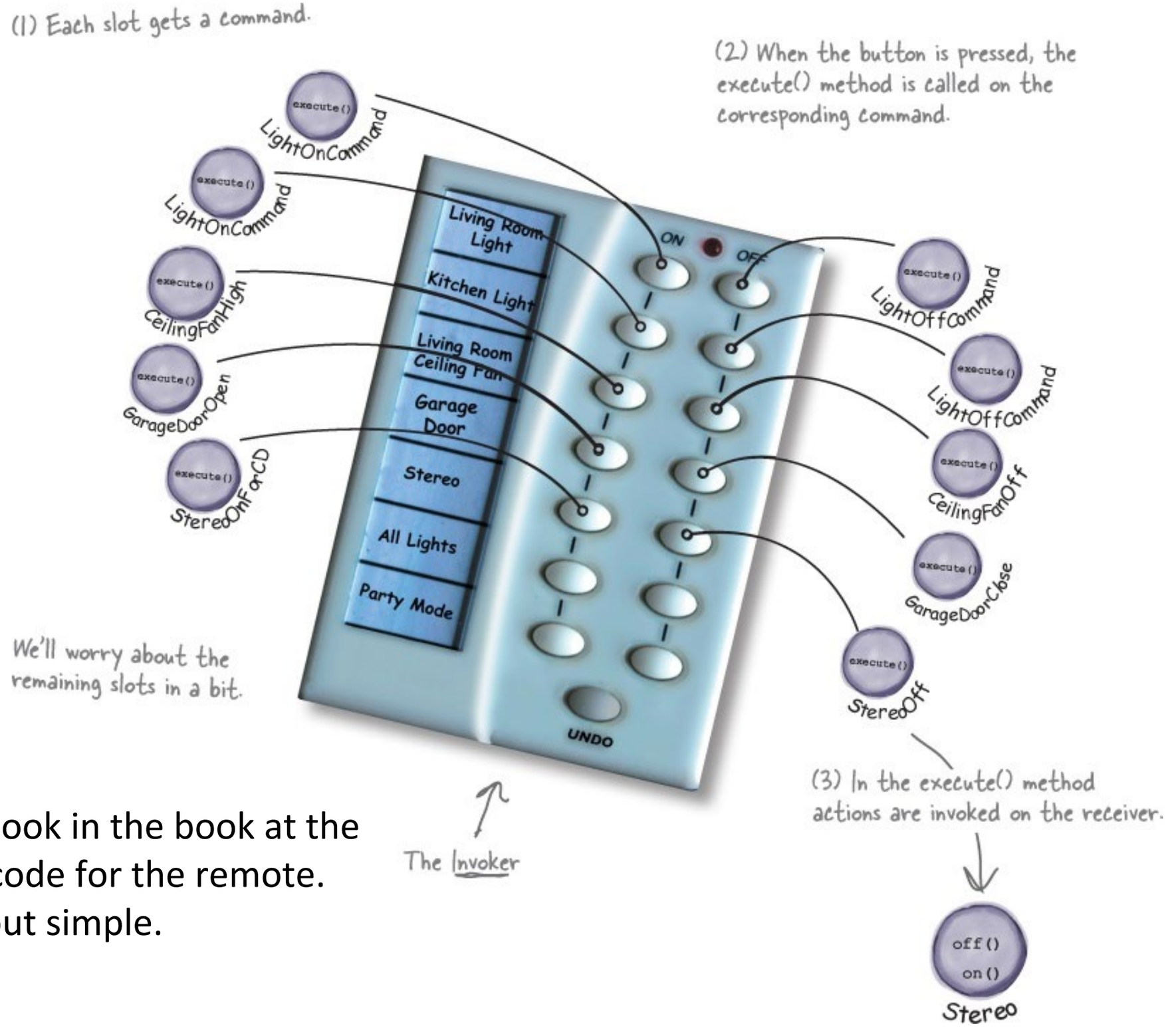


Note here that the command is delegating the action() to the receiver set by the client. If the action was simple, the command could do it directly (eliminates receiver)…

```
public void execute() {
    receiver.action()
}
```

- Client creates ConcreteCommand, sets Receiver
- Invoker holds command, calls execute()
- Command interface specifies common command methods
- ConcreteCommand is the binding between Receivers and actions
- Receiver provide actions to execute (any class can be a Receiver)

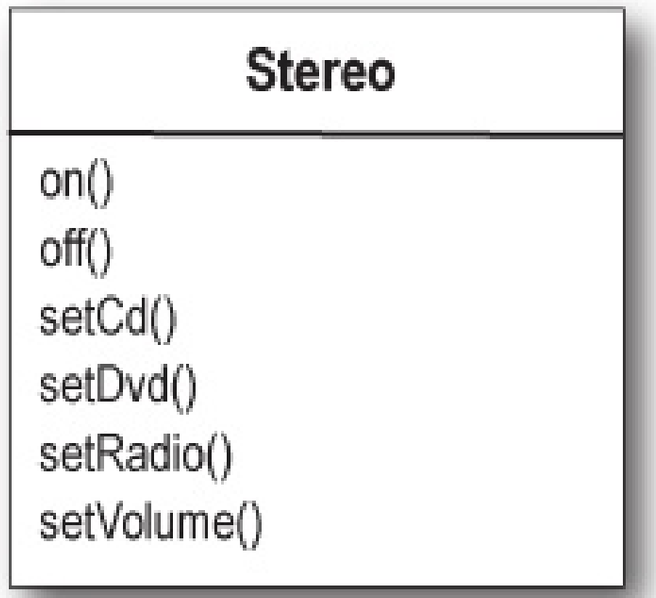
That Remote Control…



You can look in the book at the Invoker code for the remote.
It's big, but simple.

More Complicated Commands

- Most of the devices execute in their implemented Command class just call on or off – but they could do more – consider the Stereo




```
public class StereoOnWithCDCommand implements Command {
    Stereo stereo;

    public StereoOnWithCDCommand(Stereo stereo) {
        this.stereo = stereo;
    }

    public void execute() {
        stereo.on();
        stereo.setCD();
        stereo.setVolume(11);
    }
}
```

Just like the LightOnCommand, we get passed the instance of the stereo we are going to be controlling and we store it in a local instance variable.

To carry out this request, we need to call three methods on the stereo: first, turn it on, then set it to play the CD, and finally set the volume to 11. Why 11? Well, it's better than 10, right?

What about the remote buttons without commands?

- Create a command that does nothing:

```
public class NoCommand implements Command {
    public void execute()  {    }
}
```

- Sneakily, this is actually another pattern…
- This is a **Null Object Pattern**
- Null objects are used when you don’t have anything to return, but you don’t want the client to have to handle null cases

What about the undo? Undo is a method in the command interface…

```
public class LightOnCommand implements Command {
    Light light;

    public LightOnCommand(Light light) {
        this.light = light;
    }

    public void execute() {
        light.on();
    }

    public void undo() {
        light.off();
    }
}
```

execute() turns the light on, so undo() simply turns the light back off.

- The opposite case for LightOff and undo is probably easy to see?

Macro Commands

- Once we have a set of commands, it's easy to build combinations of them

```
Light light = new Light("Living Room");
TV tv = new TV("Living Room");
Stereo stereo = new Stereo("Living Room");
Hottub hottub = new Hottub();

LightOnCommand lightOn = new LightOnCommand(light);
StereoOnCommand stereoOn = new StereoOnCommand(stereo);
TVOnCommand tvOn = new TVOnCommand(tv);
HottubOnCommand hottubOn = new HottubOnCommand(hottub);

Command[] partyOn = { lightOn, stereoOn, tvOn, hottubOn};
Command[] partyOff = { lightOff, stereoOff, tvOff, hottubOff};

MacroCommand partyOnMacro = new MacroCommand(partyOn);
MacroCommand partyOffMacro = new MacroCommand(partyOff);
```

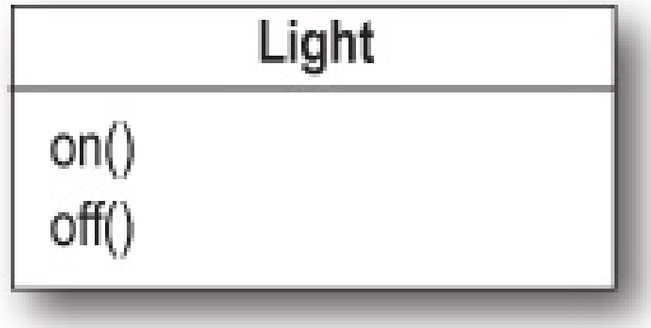
Create all the devices: a light, tv, stereo, and hot tub.

Now create all the On commands to control them.

Create an array for On and an array for Off commands...

...and create two corresponding macros to hold them.

That’s a LOT of little Command Classes!



- Maybe we could use **lambda expressions**?
- Light livingRoomLight = new Light("Living Room");
- Now, when I set the command in the Invoker, instead of passing commands, I could pass lambdas.

Here are the two lambda expressions.

```
remoteControl.setCommand(0, () -> { livingRoomLight.on(); }, () -> { livingRoomLight.off(); } );
```

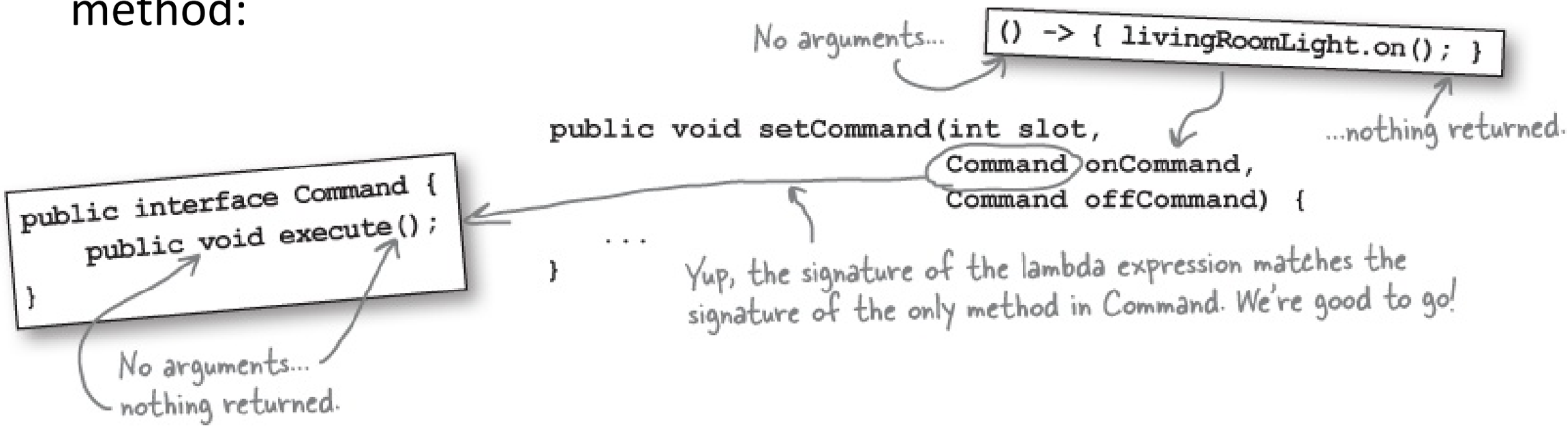
The lambdas get passed as commands to setCommand.

```
public void setCommand(int slot, Command onCommand, Command offCommand) {
    onCommands[slot] = onCommand;
    offCommands[slot] = offCommand;
}
```

- How could this work if the system is looking for an execute method to call for normal Command objects?

Lambda Magic

- The Lambda Expressions can stand in for a Command object if that Command interface has **one** method: execute() …AND…
- The Lambda Expression must have the same signature as that one method:



- The compiler will look to see that Command has one method with a matching signature, and will use the lambda instead

Java Method References

- If the lambda you're passing in has just one method, you can use a method reference to replace a single-method lambda expression
- Looks like this:

```
remoteControl.setCommand(0, livingRoomLight::on, livingRoomLight::off);
```

This is a reference to the on() method of the livingRoomLight object.

This is a reference to the off() method of the livingRoomLight object.

- Maybe

  livingRoomLight::on

- is a little cleaner than

  () -> { livingRoomLight.on(); }

- but otherwise, not much different…

Multiple actions in a Lambda

- If the lambda signature matches the signature of the one method we're calling (in this case, execute()), we can bundle up multiple actions…

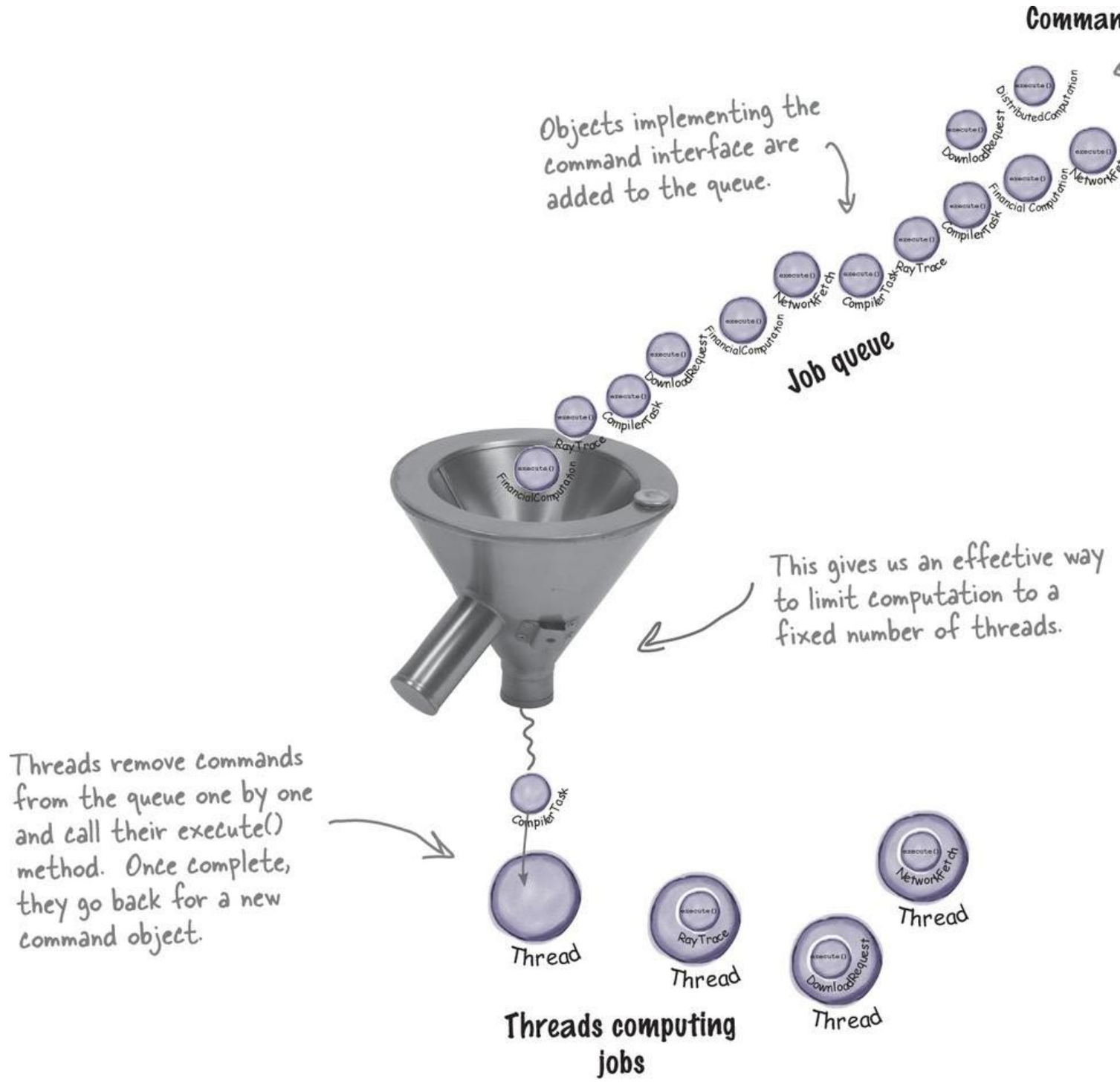
```
Command stereoOnWithCD = () -> {
    stereo.on(); stereo.setCD(); stereo.setVolume(11);
};
remoteControl.setCommand(3, stereoOnWithCD, stereo::off);
```

This lambda expression does three things (just like the stereoOnWithCDCommand's execute() method did).

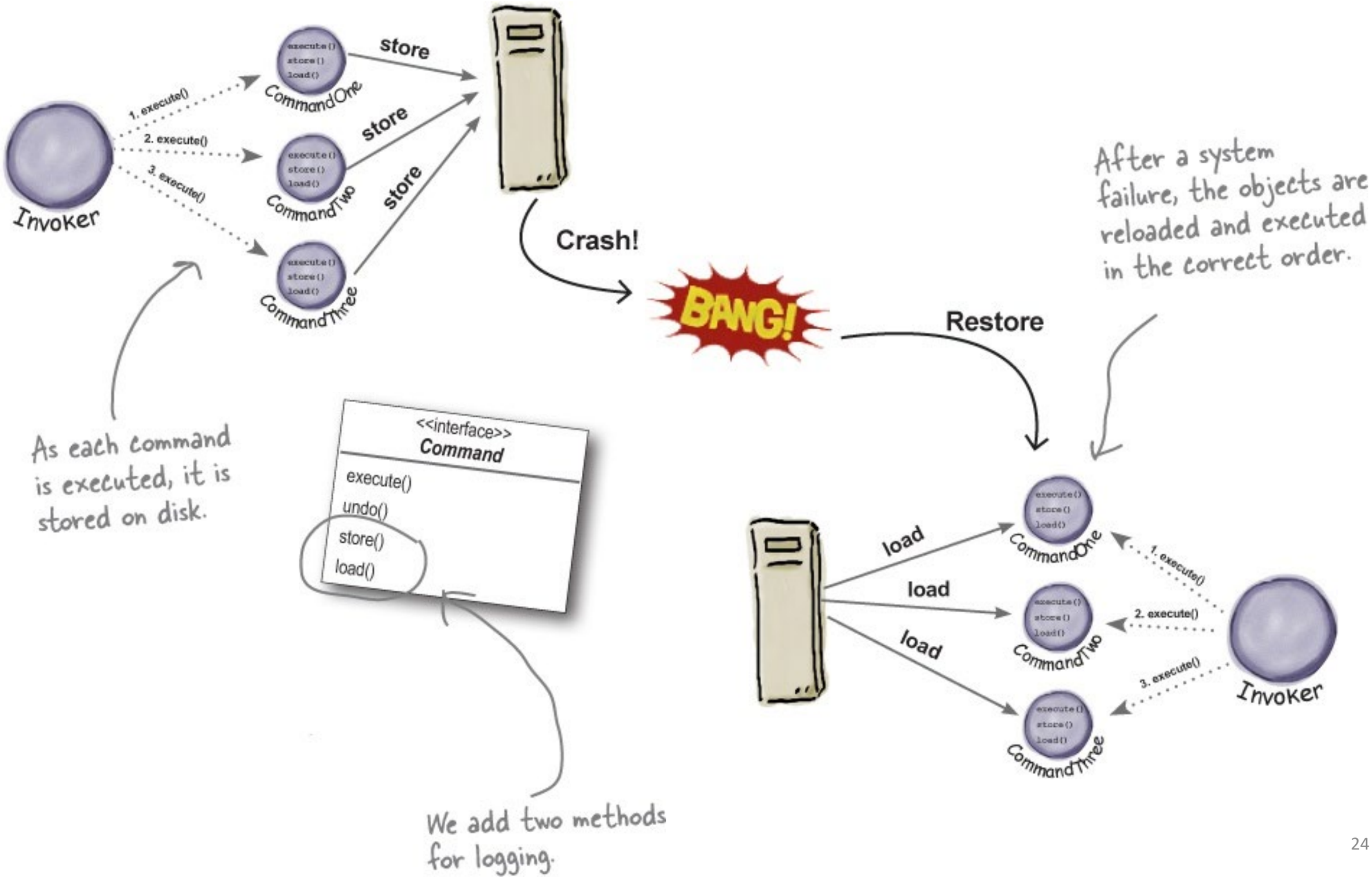
We can pass the lambda expression using its name.

- Using lambdas can really drive down the number of classes in an implementation. For the remote control example, it goes from 22 classes down to 9.
- Note that lambdas can have 0 to n parameters and return values (see the Java docs)
- Also note that this lambda implementation only works if there is a single method in the Command interface, like execute(). If you add undo(), you'll have to consider other implementation…

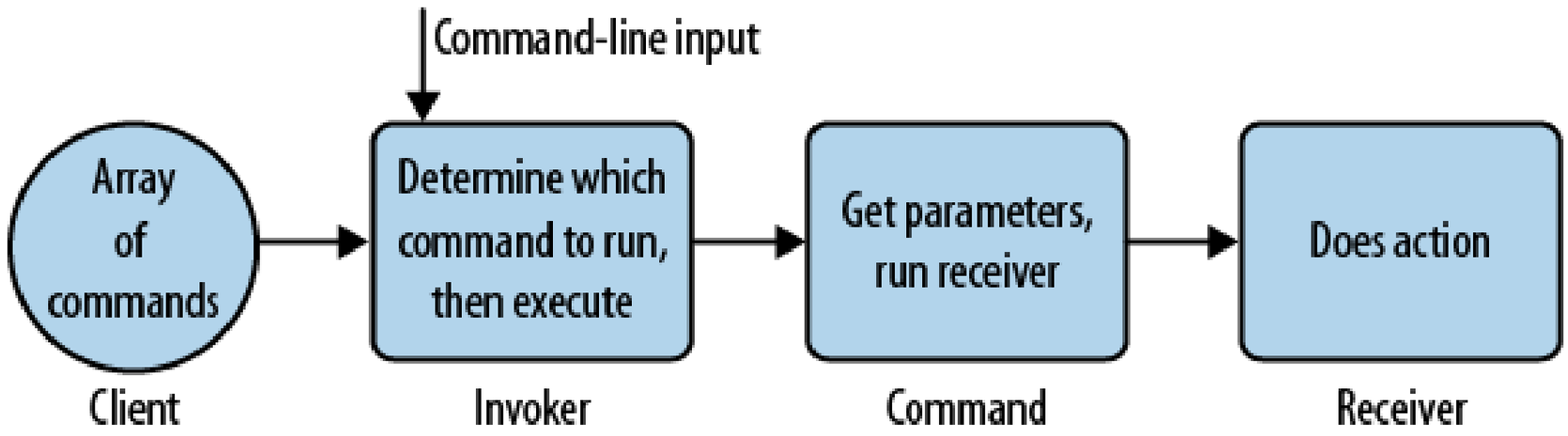
Other uses for Command: Queuing Requests



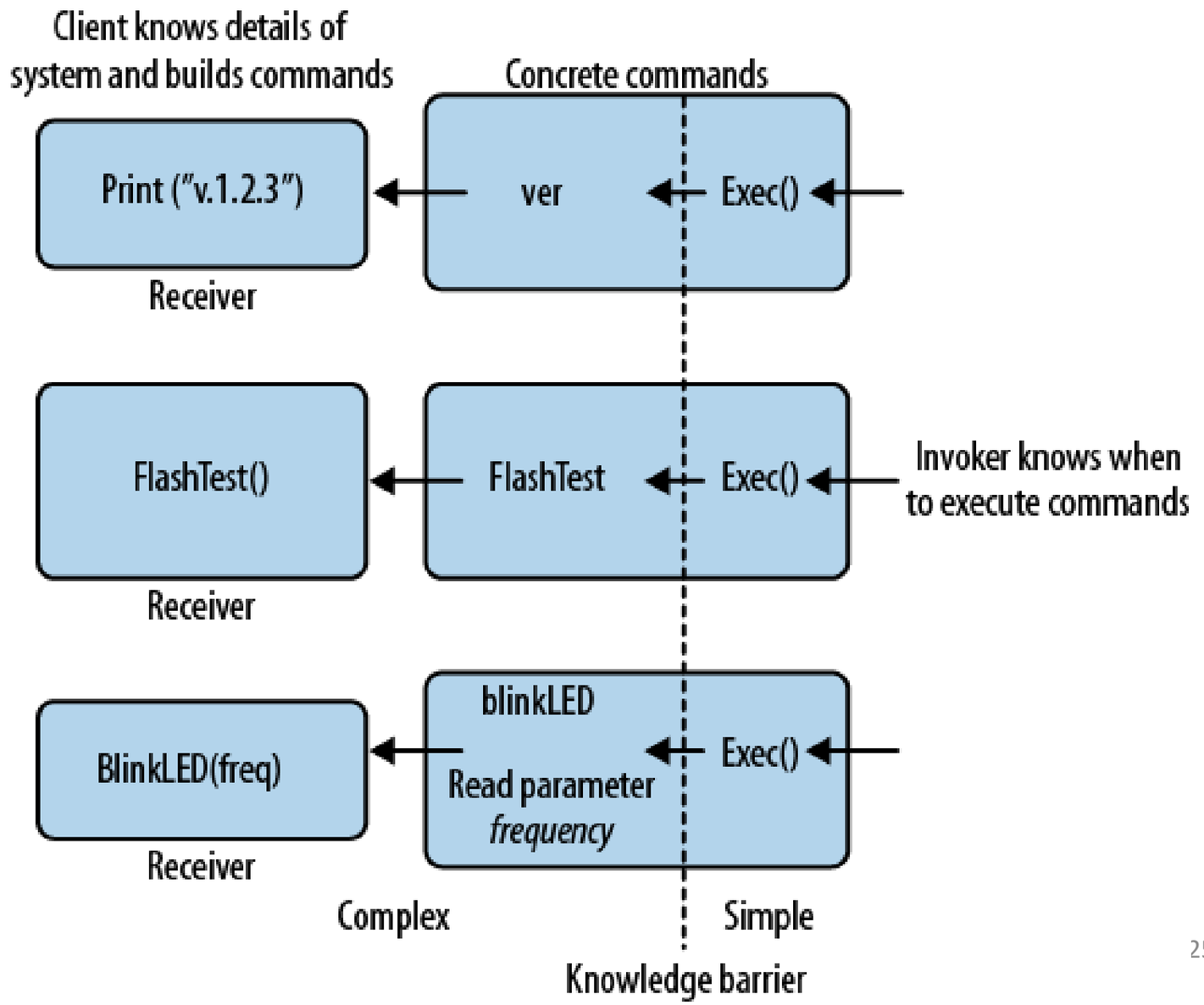
Other uses for Command: Logging Requests



One more…



- The Command Pattern popped up in my Firmware class…
  - From Making Embedded Systems, Elecia White, 2011, O'Reilly
- The pattern was used to create a framework of commands to test new boards, and to be able to easily add more tests
- Commands are C structures with a function pointer for executing an operation



Python Command Pattern Implementation

```
import abc

class Command(metaclass=abc.ABCMeta):
    # The command interface that declares a method (execute) for a particular action.
    @abc.abstractmethod
    def execute(self):
        pass

class Sandwich:
    # Receiver with method for action
    def make_sandwich(self):
        print("A sandwich is being made")

class SandwichCommand(Command):
    #A concrete / specific Command class, implementing execute()

    def __init__(self, sandwich: Sandwich):
        self._sandwich = sandwich

    def execute(self):
        self._sandwich.make_sandwich()
```

https://medium.com/@rrfd/strategy-and-command-design-patterns-wizards-and-sandwiches-applications-in-python-d1ee1c86e00f

Python Command Pattern Implementation

```
class MealInvoker:
    # Has a reference to the Command, and can execute the method

    def __init__(self, command: Command):
        self._command = command
        self._command_list = []  # type: List[Command]

    def set_command(self, command: Command):
        self.command = command

    def get_command(self):
        print(self.command.__class__.__name__)

    def add_command_to_list(self, command: Command):
        self._command_list.append(command)

    def execute_commands(self):
        # Execute all the saved commands, then empty the list.
        for cmd in self._command_list:
            cmd.execute()
        self._command_list.clear()

    def invoke(self):
        self._command.execute()
```

```
# Command pattern in action
sandwich = Sandwich()  # receiver
command_sandwich = SandwichCommand(sandwich)  # concrete command
meal_invoker = MealInvoker(command_sandwich)  # invoker
meal_invoker.invoke() # Starting the method calls
meal_invoker.add_command_to_list(command_sandwich)
meal_invoker.execute_commands()
>> A sandwich is being made
>> A sandwich is being made
```

https://medium.com/@rrfd/strategy-and-command-design-patterns-wizards-and-sandwiches-applications-in-python-d1ee1c86e00f

Command Summary

- The Command Pattern decouples an object making a Request from the one that knows how to perform it
- A Command object is at the center of this decoupling and encapsulates a Receiver with an action (or set of actions)
- An Invoker makes a request of a Command object by calling its execute() method, which invokes those actions on the receiver
- Invokers can be parameterized with Commands, even dynamically at runtime
- Commands may support undo by implementing an undo method that restores the object to its previous state before the execute() method was last called
- Meta or Macro Commands are a simple extension of Command that allow multiple commands to be invoked at once (by, for instance, creating an array of commands)
- In practice, it is not uncommon for “smart” Command objects to implement the request themselves rather than delegating to a receiver
- Commands may also be used to implement logging and transactional systems
- And don’t forget the secret Null Object Pattern we discovered

Next steps

- Project 2 is due today, noon Wed 9/30; Project 3 is due on Wed 10/14
  - Please include your PDF of UML Diagrams in the GitHub repo you turn in!
- Graduate Topic Outline is due today, noon Wed 9/30; Peer Review is due on Wed 10/14
- Semester project topic selections will be due noon Wed 10/7, this is not graded, so within a day or two of that is fine – I want to be able to review your proposed work before you start.
- Quiz 5 will open on Friday/Saturday for you
- Please take a look at the discussion topics for participation! New one is up!
- Coming up: Façade/Adapter patterns and a Pattern exercise
  - You'll want to look at the textbook chapter 7 for readings supporting the pattern lecture
- If you need help – Office hours, Piazza, e-mail – don't be afraid to ask, it's what we're here for!