GEORGE MASON UNIVERSITY

SWE 621

FALL 2022

FOLLOWING A DESIGN

LOGISTICS

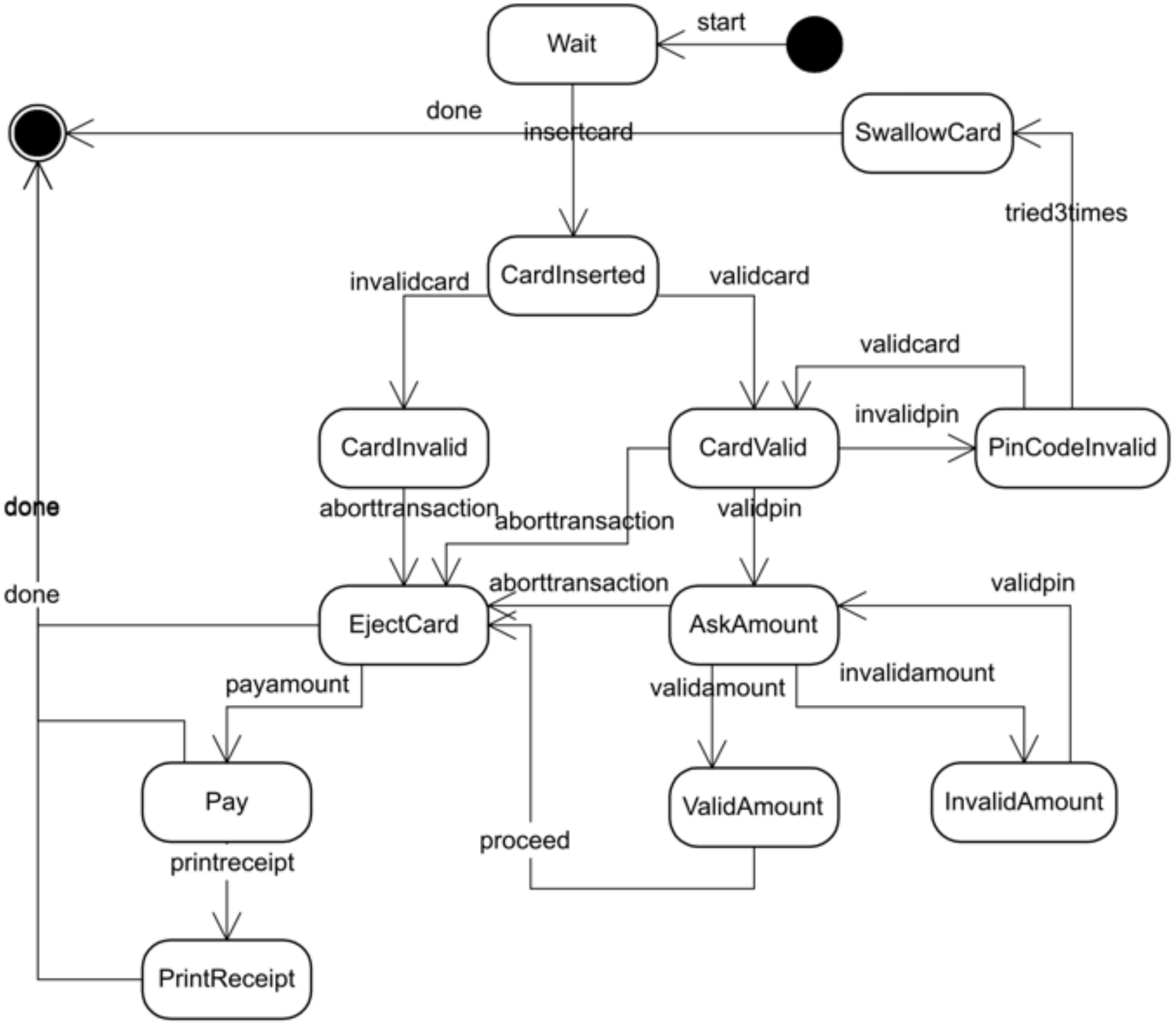
- HW4 due next week

FOLLOWING A DESIGN

- So far we've considered how design choices can help system achieve quality attributes
    - abstractions, architectural styles, design patterns
    - by minimizing risk, by following domain model, hiding decisions likely to change
- What happens when a developer makes a code change that **fails** to follow the constraints imposed by the design decision?
    - How do you **prevent** developers from not following design decisions?
- What happens when the design decision should change?
    - Requirement changes may lead to decisions no longer being effective.
    - May find better design choices as better understand problem.

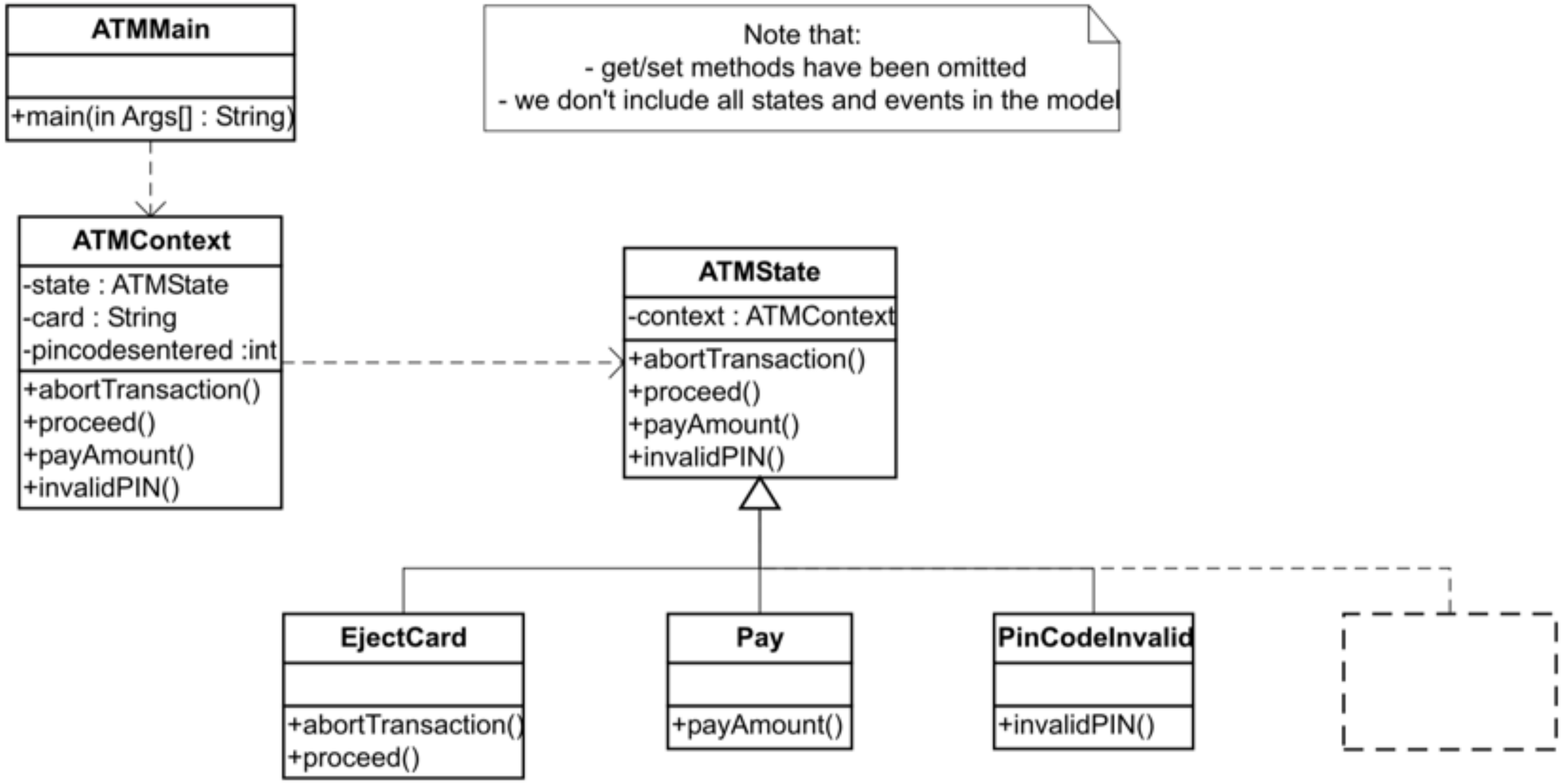
EXAMPLE: HOW SOFTWARE EVOLVES OVER TIME

- ATM Simulator
  - Describes behavior of ATM machine as user interacts with machine



V1: STATE PATTERN

- Decisions
  - Use the state pattern
  - Put data in context class
  - Make context a property of ATMState
  - Use command line for UI



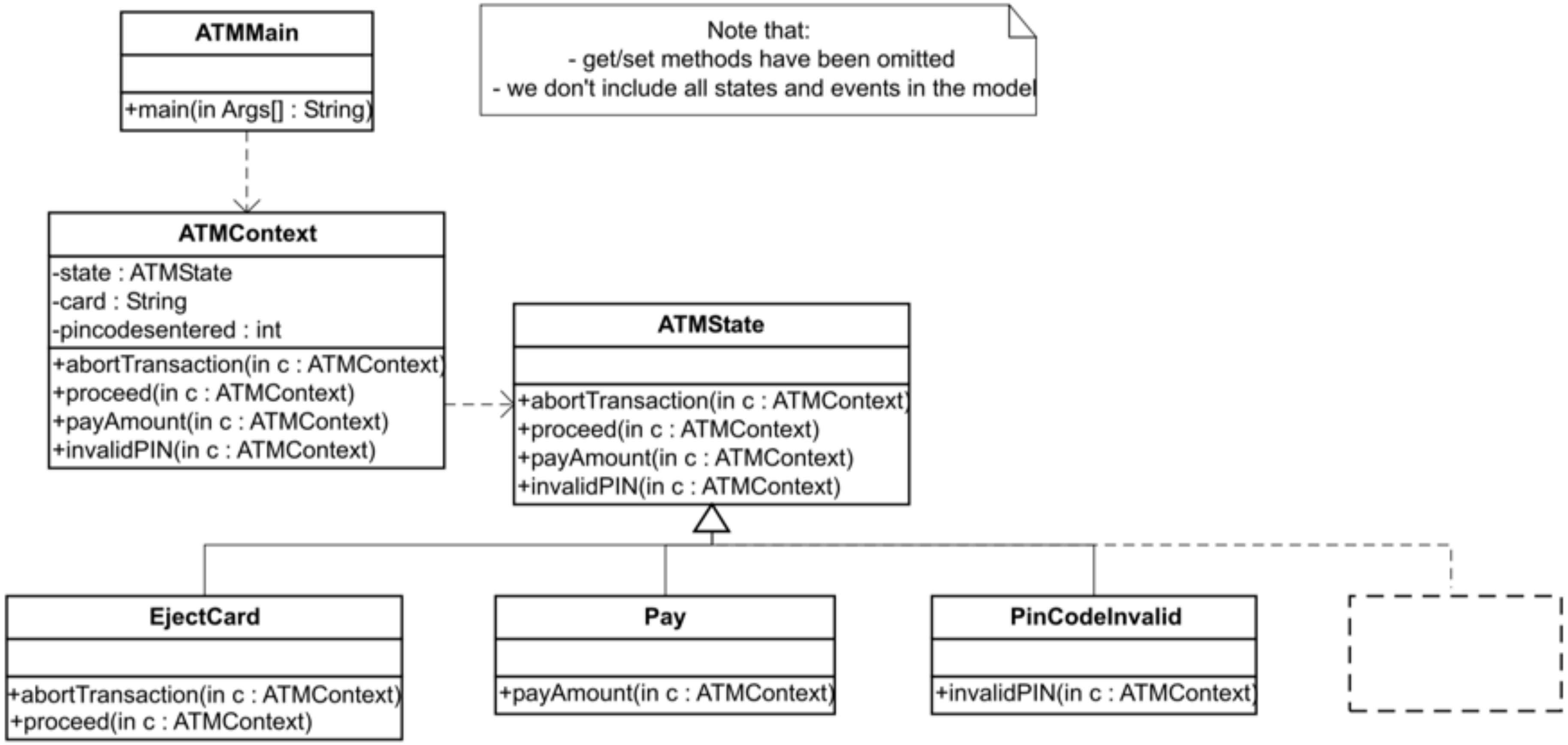
Note that:
- get/set methods have been omitted
- we don't include all states and events in the model

V1: STATE PATTERN

- ATMContext stores variables used by ATMState subclasses
  - Need to be shared between subclasses
  - Everything needs references to context class
- ATMContext contains many methods that only forward the call to the current state
- ATMContext does not check whether a particular event is supported by the current state
  - Potential for defects

V2: FLYWEIGHT

- Goals
  - Memory usage: instantiate each state class only once
  - Performance: reduce startup time for simulator

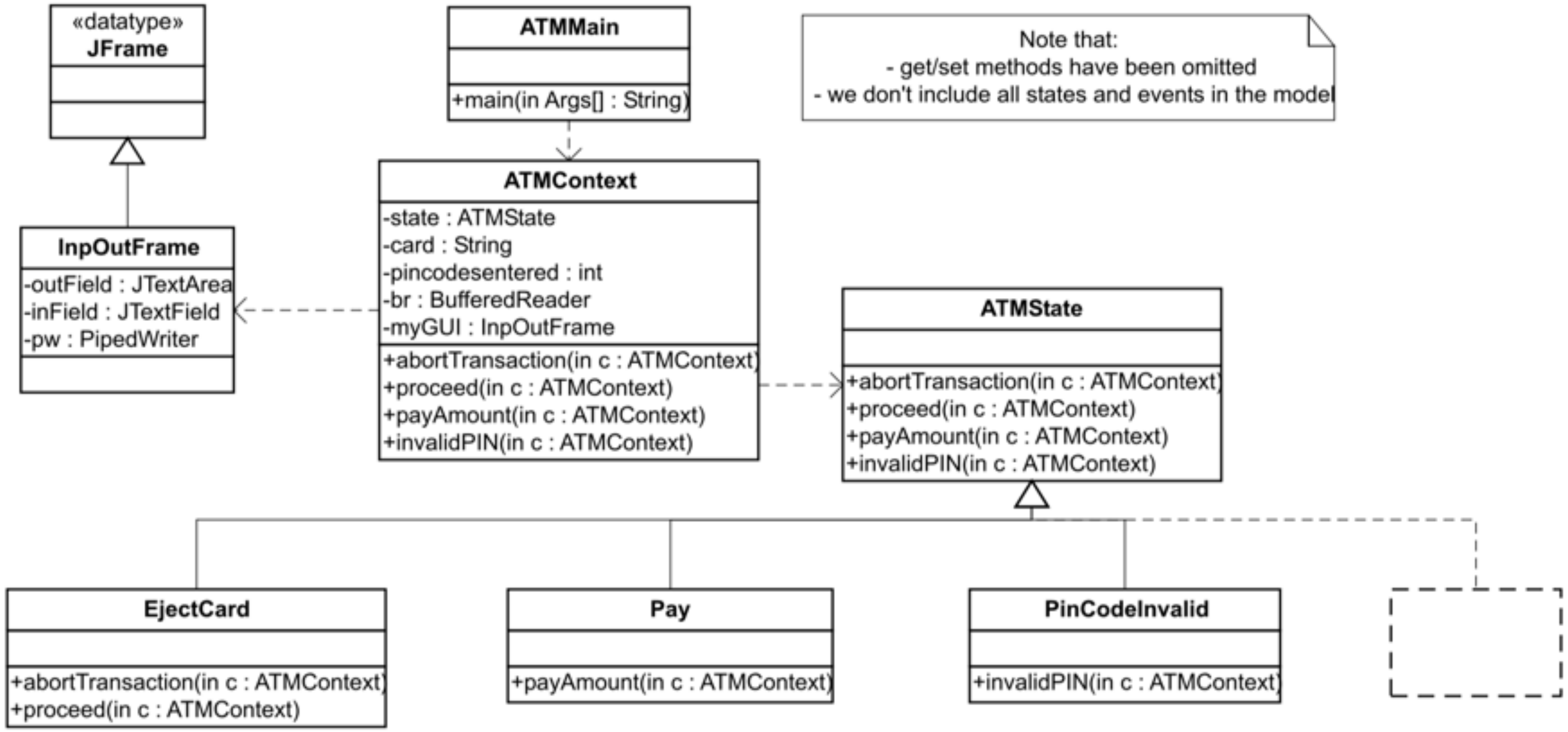

ATMMain
+main(in Args[] : String)
Note that:
- get/set methods have been omitted
- we don't include all states and events in the model
ATMContext
-state : ATMState
-card : String
-pincodesentered : int
+abortTransaction(in c : ATMContext)
+proceed(in c : ATMContext)
+payAmount(in c : ATMContext)
+invalidPIN(in c : ATMContext)
ATMState
+abortTransaction(in c : ATMContext)
+proceed(in c : ATMContext)
+payAmount(in c : ATMContext)
+invalidPIN(in c : ATMContext)
EjectCard
+abortTransaction(in c : ATMContext)
+proceed(in c : ATMContext)
Pay
+payAmount(in c : ATMContext)
PinCodeInvalid
+invalidPIN(in c : ATMContext)

V2: FLYWEIGHT

- Each state class is only created once
- Removed the context property from ATMState, added context parameter in each event method

V3: MULTIPLE INSTANCES

- Goals
    - Parallelism: enable each simulator to run in a separate thread
    - UI: support multiple simulators


«datatype»
JFrame
ATMMain
+main(in Args[] : String)
Note that:
- get/set methods have been omitted
- we don't include all states and events in the model
InpOutFrame
-outField : JTextArea
-inField : JTextField
-pw : PipedWriter
ATMContext
-state : ATMState
-card : String
-pincodesentered : int
-br : BufferedReader
-myGUI : InpOutFrame
+abortTransaction(in c : ATMContext)
+proceed(in c : ATMContext)
+payAmount(in c : ATMContext)
+invalidPIN(in c : ATMContext)
ATMState
+abortTransaction(in c : ATMContext)
+proceed(in c : ATMContext)
+payAmount(in c : ATMContext)
+invalidPIN(in c : ATMContext)
EjectCard
+abortTransaction(in c : ATMContext)
+proceed(in c : ATMContext)
Pay
+payAmount(in c : ATMContext)
PinCodeInvalid
+invalidPIN(in c : ATMContext)

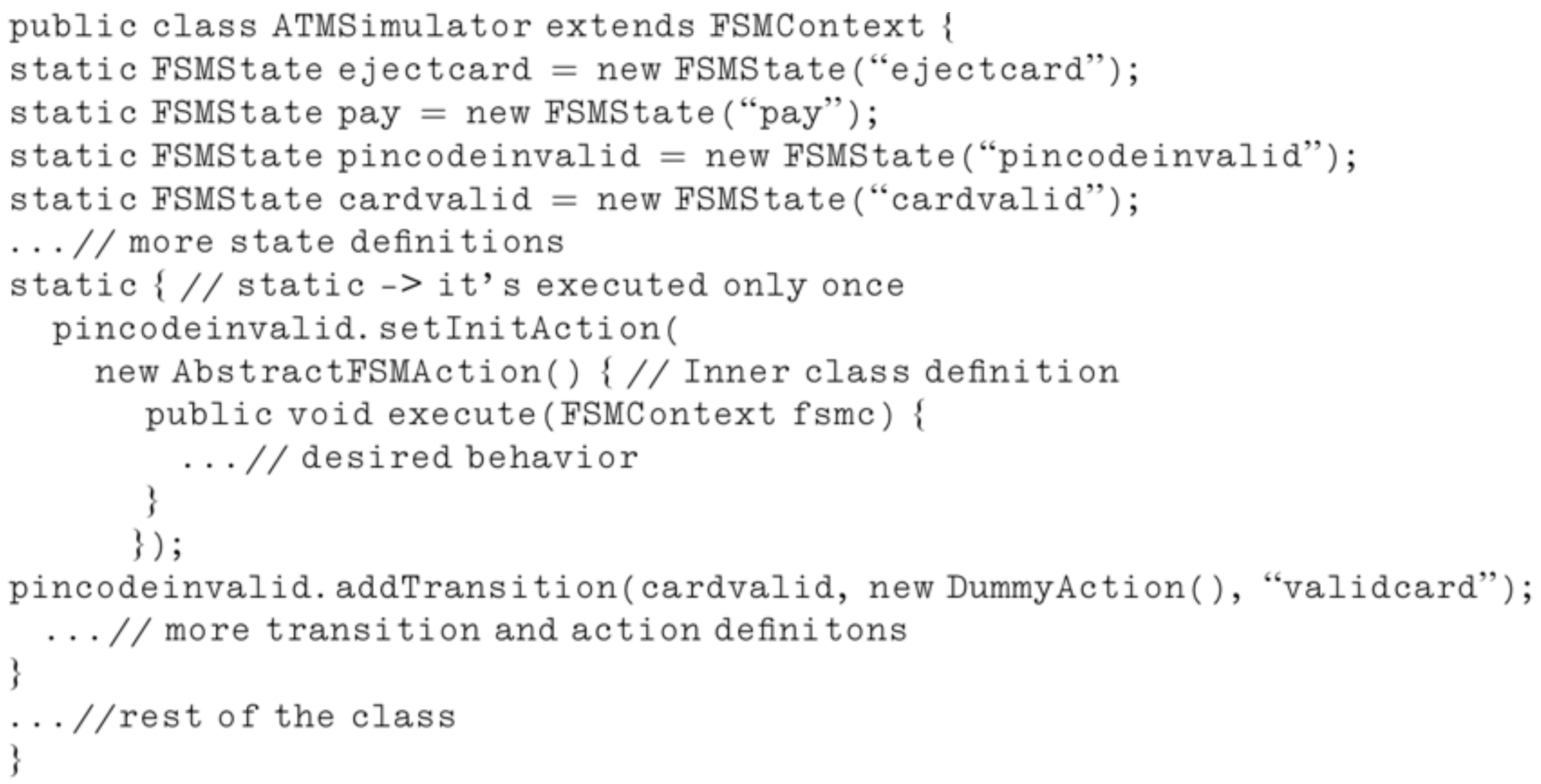
V3: MULTIPLE INSTANCES

- Replaced command line with GUI, each containing multiple windows
- Each window associated with ATMContext
- GUI connected to ATMContext with pipes and filters
    - Whenever a user enters data, can read from IOStream from GUI just as if it were the command line

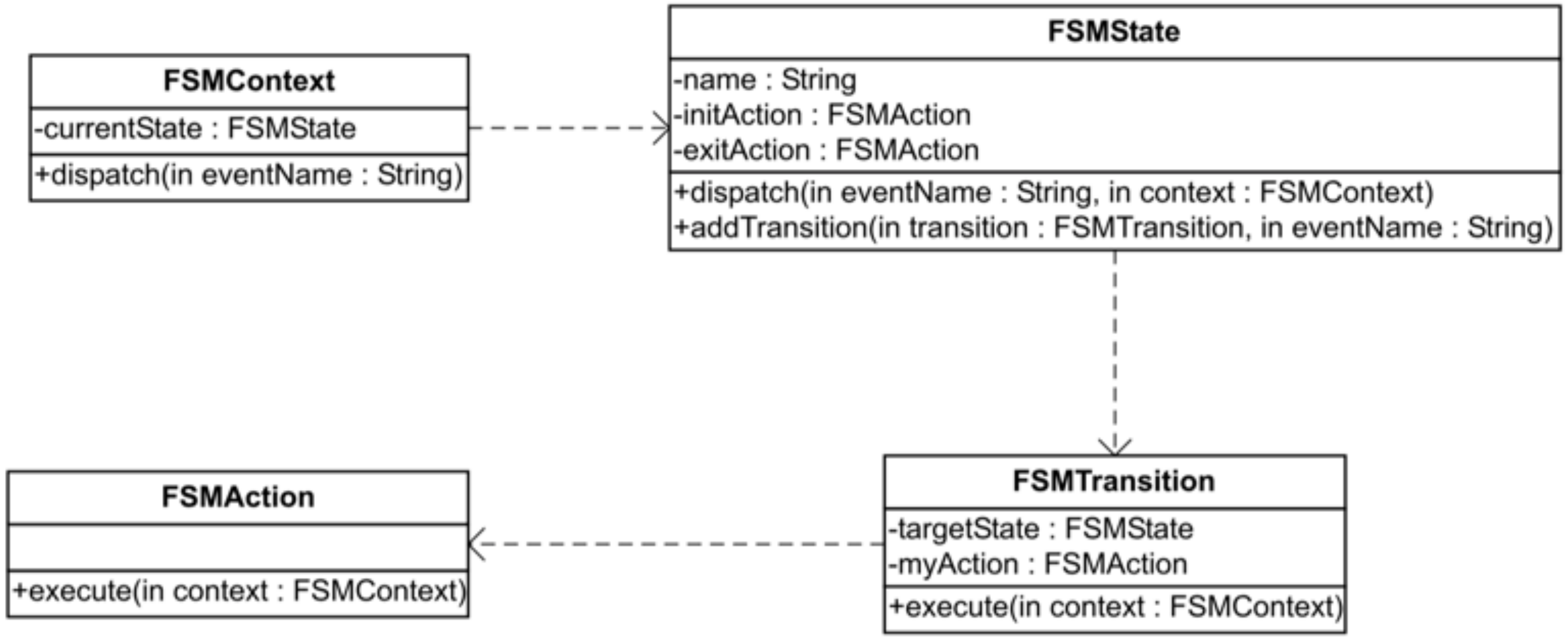
V4: DELEGATION-BASED APPROACH

- Goals
  - Configurability: allow for adding new states and transitions at runtime (e.g., machine runs out of paper)
  - Separation of concerns: decouple state machine further

V4: DELEGATION-BASED APPROACH



```
public class ATMSimulator extends FSMContext {
static FSMState ejectcard = new FSMState(“ejectcard”);
static FSMState pay = new FSMState(“pay”);
static FSMState pincodeinvalid = new FSMState(“pincodeinvalid”);
static FSMState cardvalid = new FSMState(“cardvalid”);
...// more state definitions
static { // static -> it’s executed only once
  pincodeinvalid.setInitAction(
    new AbstractFSMAction() { // Inner class definition
      public void execute(FSMContext fsmc) {
        ...// desired behavior
      }
     });
pincodeinvalid.addTransition(cardvalid, new DummyAction(), “validcard”);
  ...// more transition and action definitons
}
...//rest of the class
}
```



FSMContext
-currentState : FSMState
+dispatch(in eventName : String)

FSMState
-name : String
-initAction : FSMAction
-exitAction : FSMAction
+dispatch(in eventName : String, in context : FSMContext)
+addTransition(in transition : FSMTransition, in eventName : String)

FSMAction
+execute(in context : FSMContext)

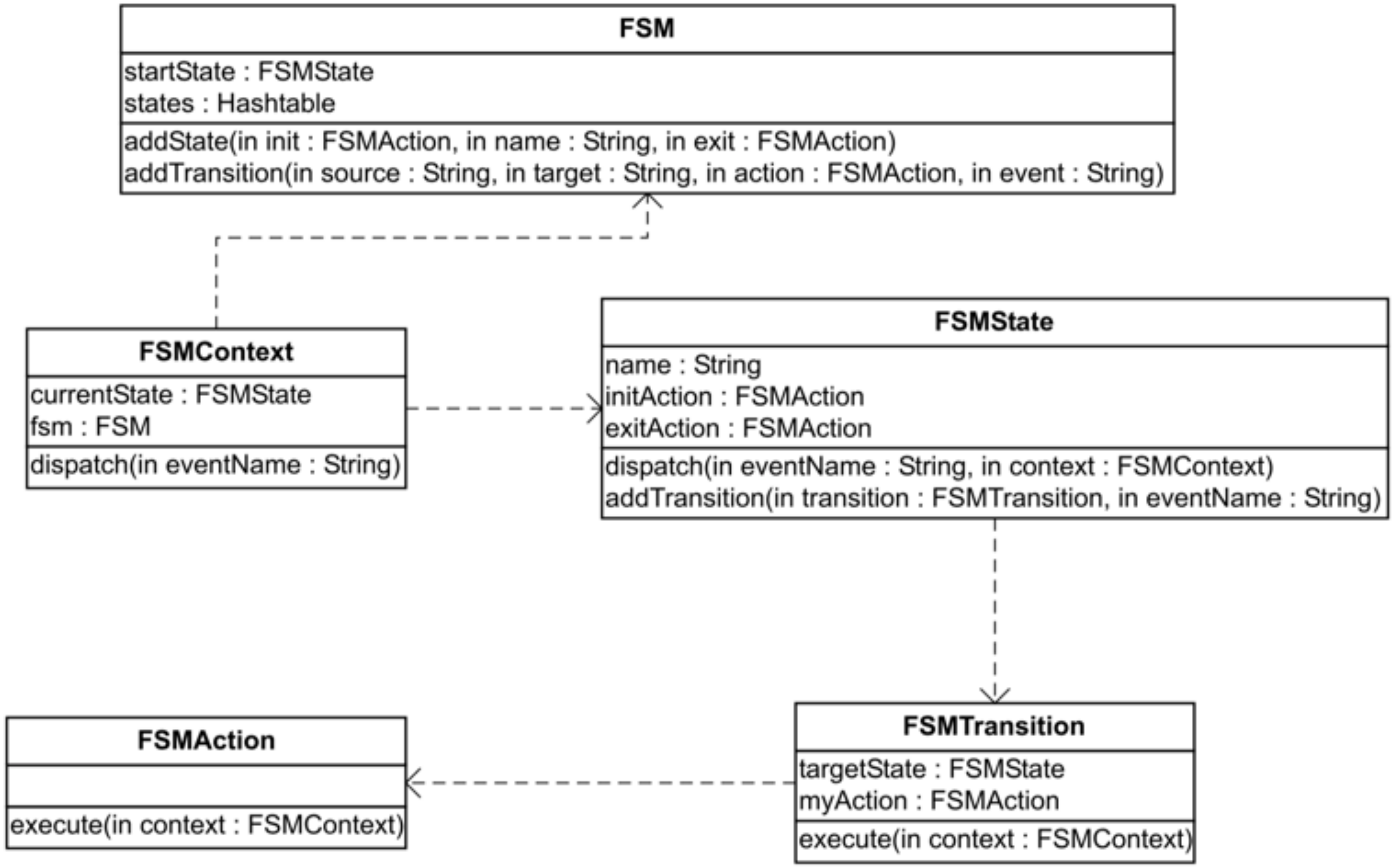
FSMTransition
-targetState : FSMState
-myAction : FSMAction
+execute(in context : FSMContext)

V4: DELEGATION BASED APPROACH

- Use delegation rather than inheritance
  - States no longer subclass FSMState
  - Transitions are now first class
  - Transitions delegate behavior to Action

V5: DECOUPLING

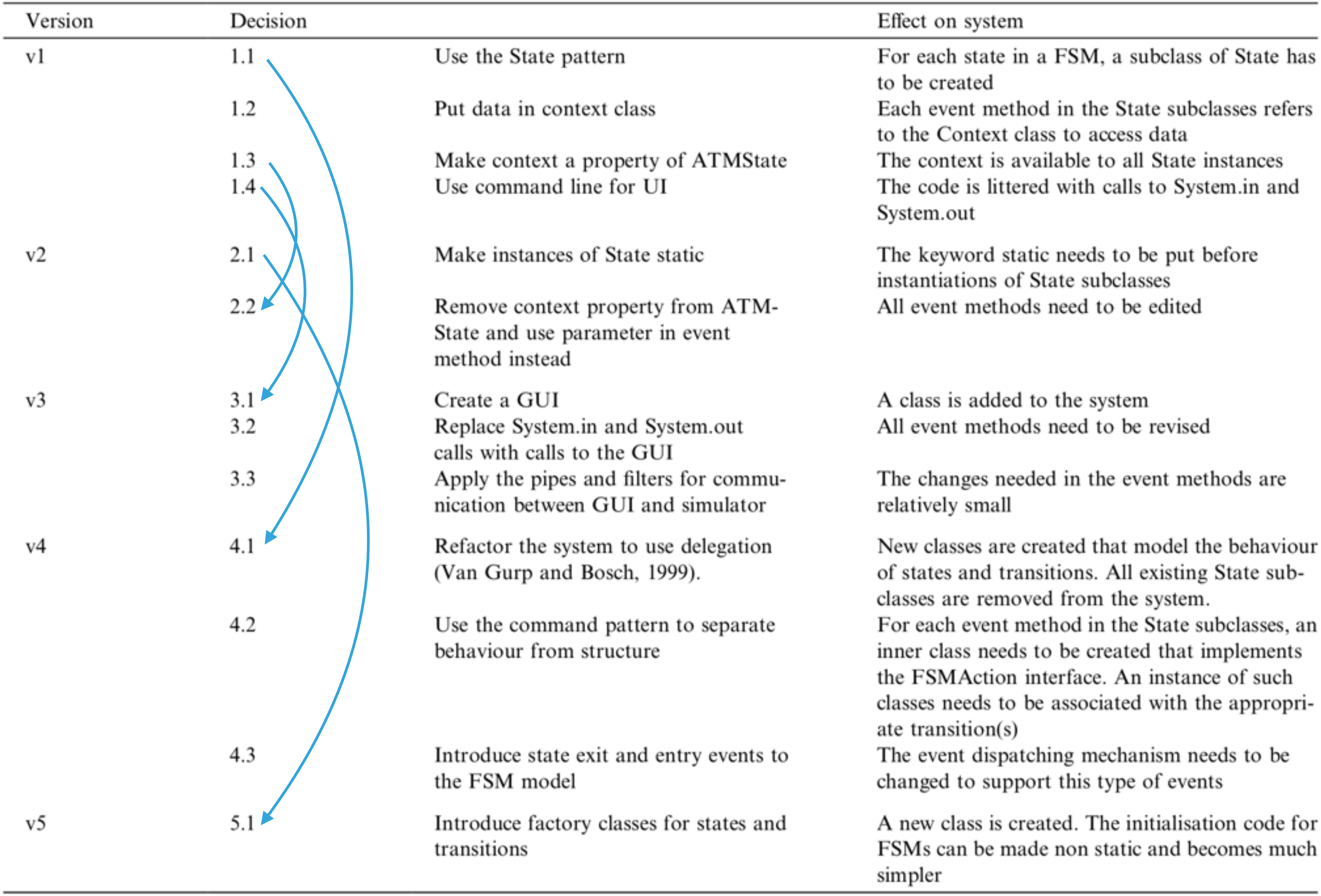
- Goals
  - Reduce use of static


FSM
startState : FSMState
states : Hashtable
addState(in init : FSMAction, in name : String, in exit : FSMAction)
addTransition(in source : String, in target : String, in action : FSMAction, in event : String)
FSMContext
currentState : FSMState
fsm : FSM
dispatch(in eventName : String)
FSMState
name : String
initAction : FSMAction
exitAction : FSMAction
dispatch(in eventName : String, in context : FSMContext)
addTransition(in transition : FSMTransition, in eventName : String)
FSMAction
execute(in context : FSMContext)
FSMTransition
targetState : FSMState
myAction : FSMAction
execute(in context : FSMContext)

- Introduce FSM, which separates responsibility of storing FSM from dispatching events

SUMMARY OF EVOLUTION

- Later decisions revised earlier



Version	Decision		Effect on system
v1	1.1	Use the State pattern	For each state in a FSM, a subclass of State has to be created
	1.2	Put data in context class	Each event method in the State subclasses refers to the Context class to access data
	1.3	Make context a property of ATMState	The context is available to all State instances
	1.4	Use command line for UI	The code is littered with calls to System.in and System.out
v2	2.1	Make instances of State static	The keyword static needs to be put before instantiations of State subclasses
	2.2	Remove context property from ATMState and use parameter in event method instead	All event methods need to be edited
v3	3.1	Create a GUI	A class is added to the system
	3.2	Replace System.in and System.out calls with calls to the GUI	All event methods need to be revised
	3.3	Apply the pipes and filters for communication between GUI and simulator	The changes needed in the event methods are relatively small
v4	4.1	Refactor the system to use delegation (Van Gurp and Bosch, 1999).	New classes are created that model the behaviour of states and transitions. All existing State subclasses are removed from the system.
	4.2	Use the command pattern to separate behaviour from structure	For each event method in the State subclasses, an inner class needs to be created that implements the FSMAction interface. An instance of such classes needs to be associated with the appropriate transition(s)
	4.3	Introduce state exit and entry events to the FSM model	The event dispatching mechanism needs to be changed to support this type of events
v5	5.1	Introduce factory classes for states and transitions	A new class is created. The initialisation code for FSMs can be made non static and becomes much simpler

SUMMARY OF EVOLUTION

- Design decisions changed over time
  - Driven by making a particular usage or scenario easier
  - Reasons may not be apparent without knowing these scenarios
- Easy to lose track of decisions
  - Constant change makes it harder to stay up to date with the current version of each design decision
  - Risk that might make change inconsistent with design
  - Risk that when changing a decision might not update everything required

SOFTWARE EVOLUTION

- As requirements are added and change, code must implement these changes.
- This requires making changes to system that are either
  - consistent with the existing design
  - changing decisions to better accommodate these new requirements, updating the relevant implementation

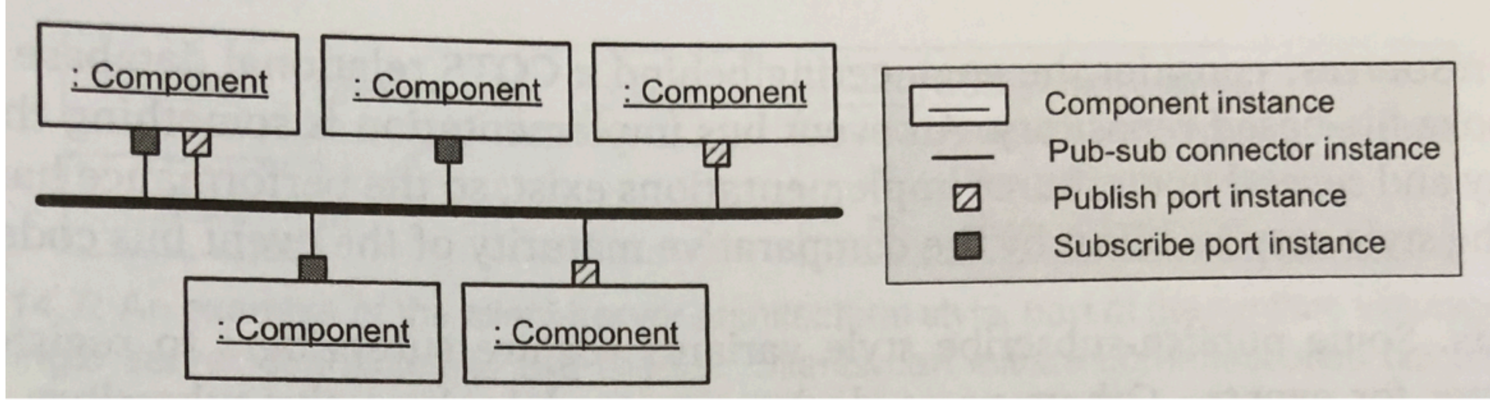
ARCHITECTURAL EROSION

- Software architectural erosion (or decay): the gap between the architecture **as designed** as an **as built**
    - e.g., intended to be a pipes and filters architecture, but isn't entirely
- Consequences of design decision are no longer achieved
    - if decision helped enable maintainability, it does no longer
- May sometimes lead to behaviorally observable defects, but not always

CODEBASES TEND TO DECAY OVER TIME

- Study of large software system, as observed through commit data
- Over time
  - Increase in # of files touched per commit
  - Increase in # of modules touched per commit
  - These increases lead to increased effort to make change
  - Relationship between edits and defects introduced

S. G. Eick, T. L. Graves, A. F. Karr, J. Marron, and A. Mockus. Does code decay? Assessing the evidence from change management data. IEEE Trans. Softw. Eng. (TSE), 27(1):1–12, Jan 2001.



AN EXAMPLE

- You've built a system following the publish / subscribe architectural style.
- Wanted to enable adding and removing components without impacting existing code
- Constraints
  - Components do not know why an event is published
  - Subscribing components do not know **who** published event, depending on event type rather than specific publisher

IN CLASS ACTIVITY

- Imagine a publish subscribe system which contains the following events
  - UserInput, ScreenResize, AppStart, AppClosing
- Imagine a developer who implements functionality which should execute whenever the screen resizes.
  - To do this, they look for a message from the RenderLoop class rather than looking for a ScreenResize event.
- What are potential consequences of this?

TECHNICAL DEBT

- Sometime you know that you've broken the design, but still decide to do it anyway.
- Why? Schedule pressure.
- But.... then have to live with the consequences
  - Changes get more expensive

MANAGING TECHNICAL DEBT

- Debt metaphor: deferred some of the work necessary to complete changes to the future
  - It passes these tests, but violates design principles that enable extensibility and maintainability.
- Need to have a plan to pay down debt.
  - Plan work to improve design to make it again consistent with design.

WHAT TO DO ABOUT CODE DECAY?

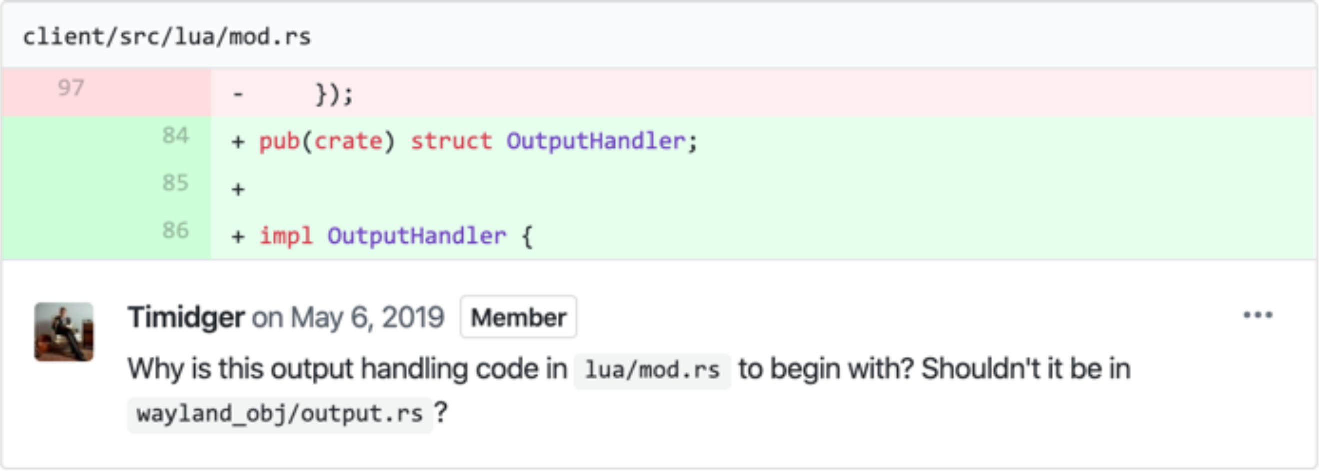
- Prevent code decay
  - Better communicate design to developers
  - Check that changes are consistent with design
- Fix code decay after it occurs
  - Refactor code to be consistent with design
  - Change code to be consistent with design changes

BETTER COMMUNICATE DESIGN TO DEVELOPERS

- How does a developer know that there's a design decision they should follow?
  - Ask a teammate
  - Read a comment
  - Read documentation
    - e.g., in our codebase, we only create element x by doing y.

CHECK THAT CHANGES ARE CONSISTENT WITH DESIGN

- Code reviews offer important quality gate
- Before any change is committed, another developer must review the a delta of the code change
  - That developer looks for potential defects in the code as well as violations of design decisions.
  - Gives comments, which original developer must then fix before code is committed

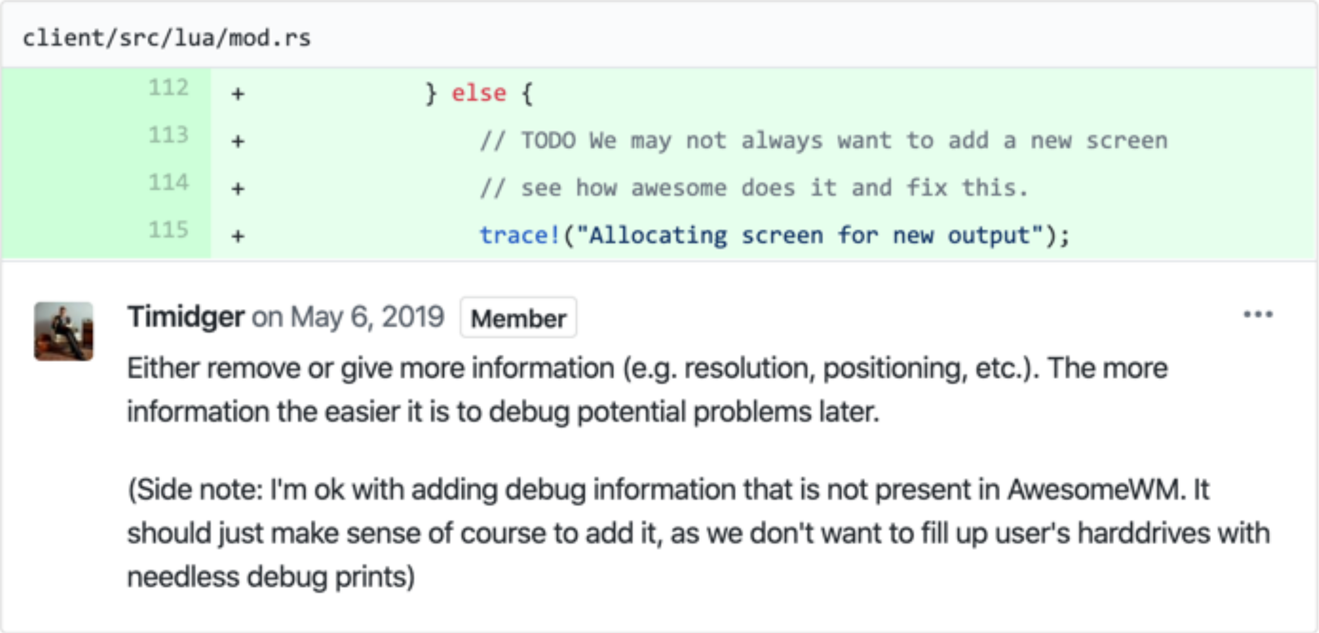


client/src/lua/mod.rs

```
-     });
+ pub(crate) struct OutputHandler;
+
+ impl OutputHandler {
```

Timidger on May 6, 2019 Member

Why is this output handling code in `lua/mod.rs` to begin with? Shouldn't it be in `wayland_obj/output.rs` ?



client/src/lua/mod.rs

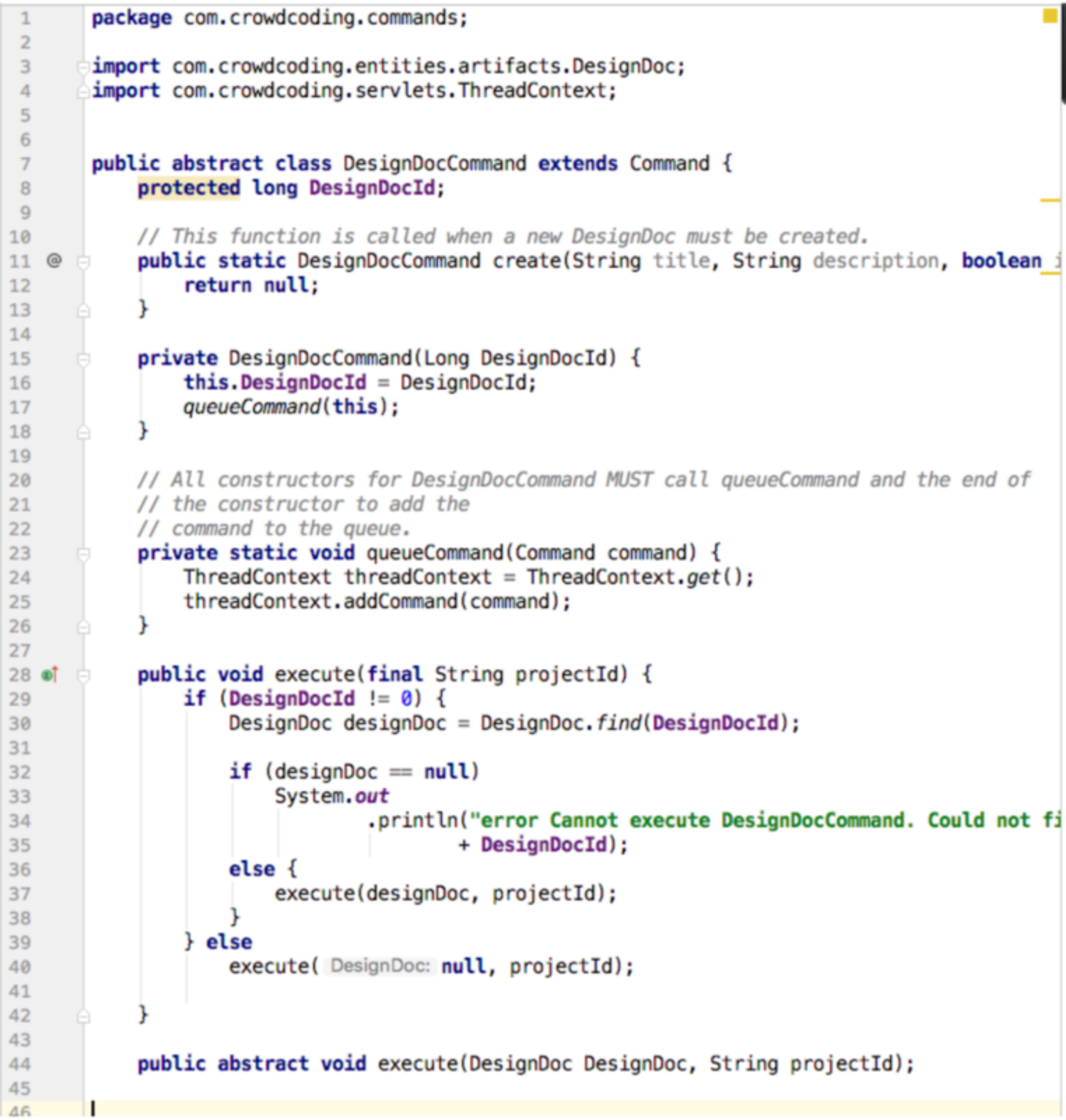
```
+                 } else {
+                     // TODO We may not always want to add a new screen
+                     // see how awesome does it and fix this.
+                     trace!("Allocating screen for new output");
```

Timidger on May 6, 2019 Member

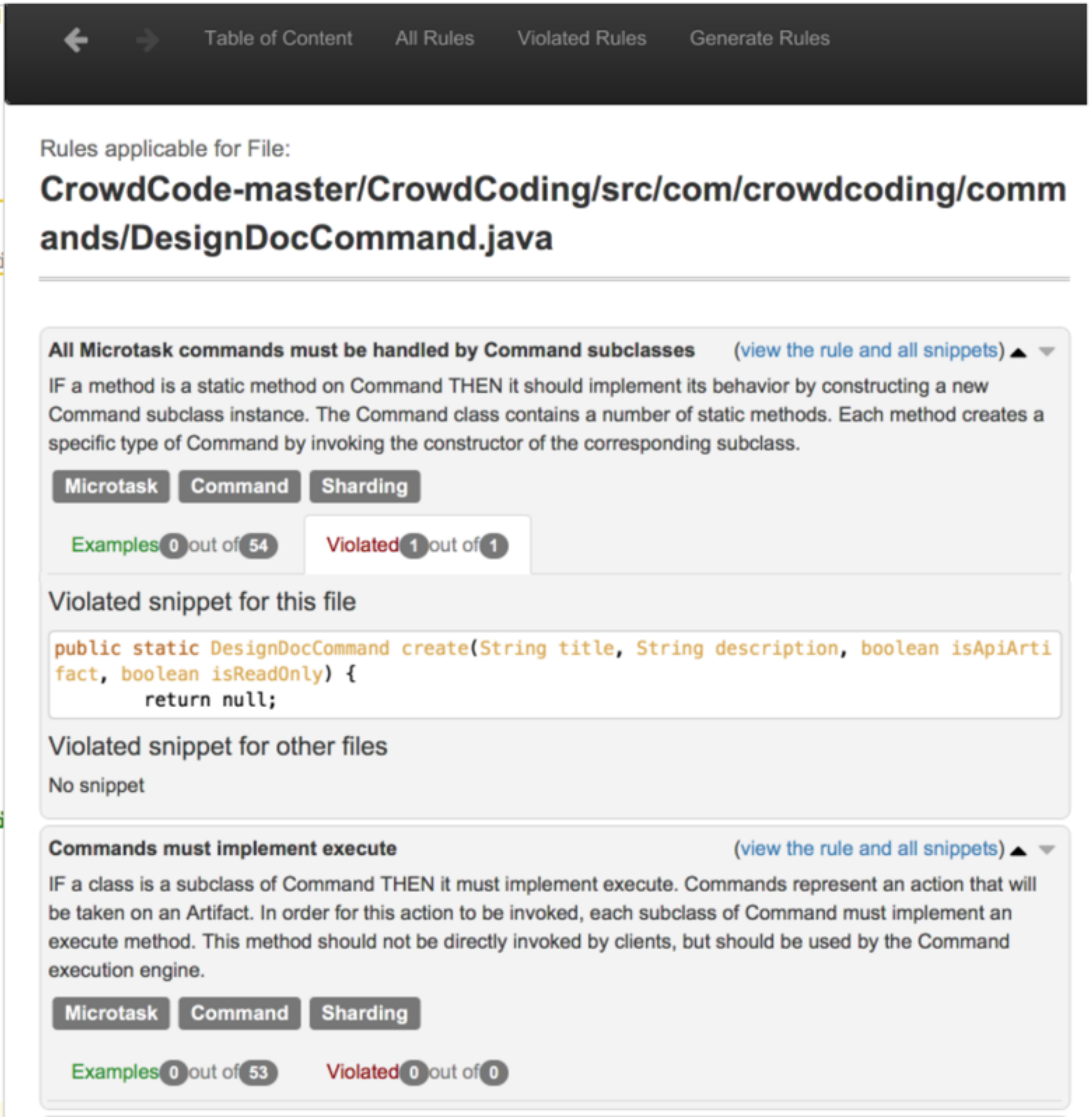
Either remove or give more information (e.g. resolution, positioning, etc.). The more information the easier it is to debug potential problems later.

(Side note: I'm ok with adding debug information that is not present in AwesomeWM. It should just make sense of course to add it, as we don't want to fill up user's harddrives with needless debug prints)

BETTER SOLUTION: TOOL SUPPORT FOR SYNCHRONIZING DECISIONS AND CODE



```java
package com.crowdcoding.commands;

import com.crowdcoding.entities.artifacts.DesignDoc;
import com.crowdcoding.servlets.ThreadContext;


public abstract class DesignDocCommand extends Command {
    protected long DesignDocId;

    // This function is called when a new DesignDoc must be created.
    public static DesignDocCommand create(String title, String description, boolean i
        return null;
    }

    private DesignDocCommand(Long DesignDocId) {
        this.DesignDocId = DesignDocId;
        queueCommand(this);
    }

    // All constructors for DesignDocCommand MUST call queueCommand and the end of
    // the constructor to add the
    // command to the queue.
    private static void queueCommand(Command command) {
        ThreadContext threadContext = ThreadContext.get();
        threadContext.addCommand(command);
    }

    public void execute(final String projectId) {
        if (DesignDocId != 0) {
            DesignDoc designDoc = DesignDoc.find(DesignDocId);

            if (designDoc == null)
                System.out
                        .println("error Cannot execute DesignDocCommand. Could not fi
                                + DesignDocId);
            else {
                execute(designDoc, projectId);
            }
        } else
            execute( DesignDoc: null, projectId);

    }

    public abstract void execute(DesignDoc DesignDoc, String projectId);

```



Rules applicable for File:

CrowdCode-master/CrowdCoding/src/com/crowdcoding/commands/DesignDocCommand.java

All Microtask commands must be handled by Command subclasses (view the rule and all snippets)

IF a method is a static method on Command THEN it should implement its behavior by constructing a new Command subclass instance. The Command class contains a number of static methods. Each method creates a specific type of Command by invoking the constructor of the corresponding subclass.

Microtask Command Sharding

Examples 0 out of 54 Violated 1 out of 1

Violated snippet for this file

```java
public static DesignDocCommand create(String title, String description, boolean isApiArtifact, boolean isReadOnly) {
        return null;
```

Violated snippet for other files

No snippet

Commands must implement execute (view the rule and all snippets)

IF a class is a subclass of Command THEN it must implement execute. Commands represent an action that will be taken on an Artifact. In order for this action to be invoked, each subclass of Command must implement an execute method. This method should not be directly invoked by clients, but should be used by the Command execution engine.

Microtask Command Sharding

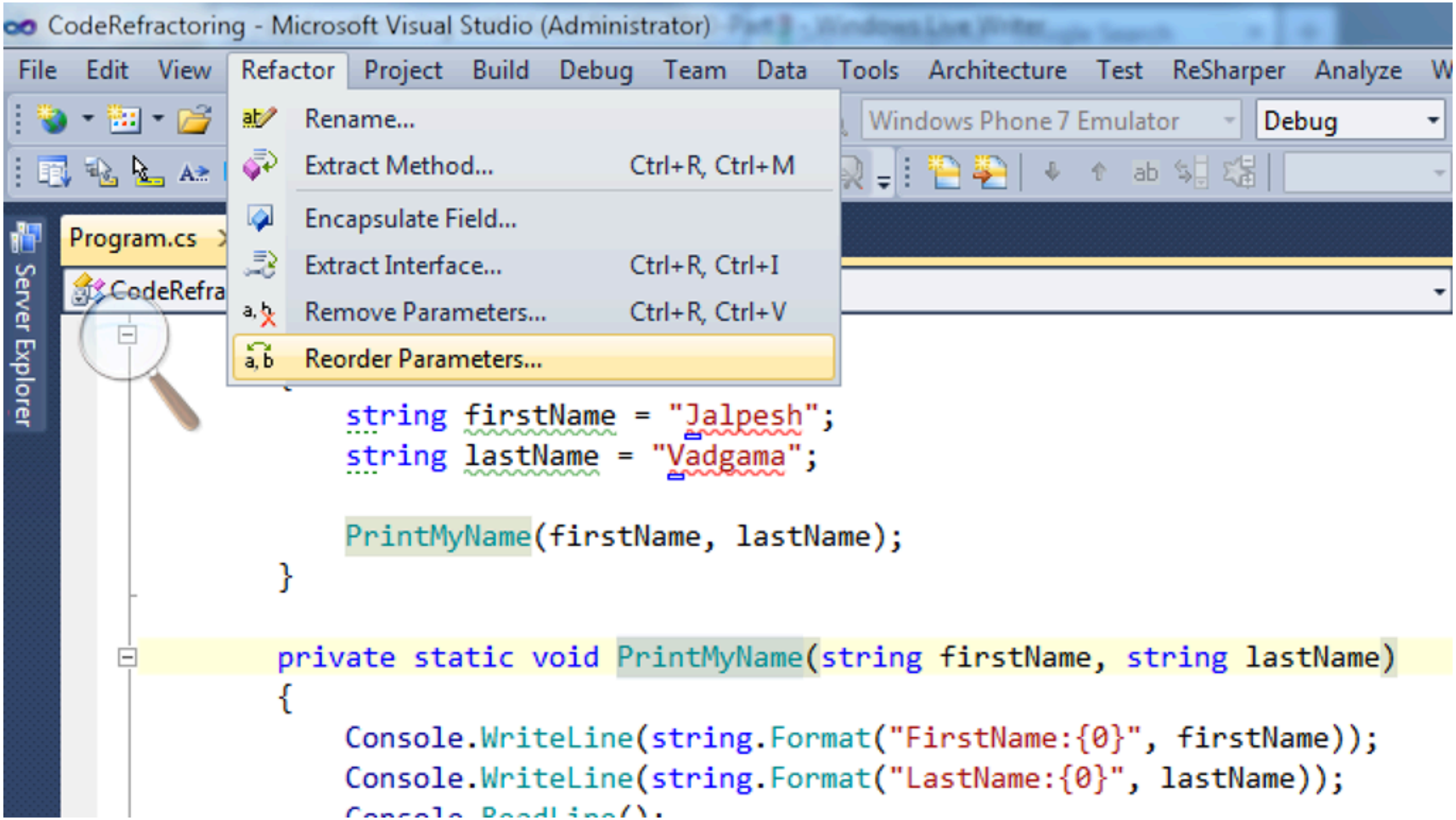
Examples 0 out of 53 Violated 0 out of 0

Sahar Mehrpour, Thomas D. LaToza, and Rahul K. Kindi. (2020). Active Documentation: Helping Developers Follow Design Decisions. Symposium on Visual Languages and Human-Centric Computing.

FIX CODE DECAY AFTER IT OCCURS

- Make changes that improve the **design** of the code without changing the **behavior**: refactoring
  - Goal: before and after change, code should behave **exactly** the same
- Involves moving and renaming functionality
- Modern IDEs support automatic low-level refactorings
  - e.g., move method.
  - Finds references to functionality and updates
  - Tries to guarantee that defects are not inserted.
- Often need to make many low-level changes to achieve higher-level goal
  - Many may not be supported directly through automated refactoring

EXAMPLE: REFACTORING SUPPORT



```
        string firstName = "Jalpesh";
        string lastName = "Vadgama";

        PrintMyName(firstName, lastName);
    }

    private static void PrintMyName(string firstName, string lastName)
    {
        Console.WriteLine(string.Format("FirstName:{0}", firstName));
        Console.WriteLine(string.Format("LastName:{0}", lastName));
        Console.ReadLine();
```

SOME EXAMPLES OF REFACTORINGS

- Encapsulate field – force code to access the field with getter and setter methods
- Generalize type – create more general types to allow for more code sharing
- Replace conditional with polymorphism
- Extract class: moves part of the code from an existing class into a new class.
- Extract method: turn part of a larger method into a new method.
- Move method or move field: move to a more appropriate class or source file
- Rename method or rename field: changing the name into a new one that better reveals its purpose
- Pull up: move to a superclass
- Push down: move to a subclass

SUMMARY

- As software evolves, its requirements may change, necessitating changes to the implementation
- Code that is inconsistent with the design introduces code decay, where expected consequences of design decisions are no longer realized
- Code decay makes code harder to change and can lead to defects
- To reduce code decay, important to prevent code decay and fix it when it occurs

IN CLASS ACTIVITY

SKETCH V6 ATM IMPLEMENTATION

- Form group of 2 or 3, pick an OO language (e.g., Java, C++, Python)
- Start with V5 ATM implementation
- Goal: make it possible to have multiple ATM implementations for separate ATM machines.
    - Clients should be able to request an ATM be created without having to depend on **which** ATM implementation is created
    - Client:
        - ATM atm = getNewATM();   // Implementation could decide to return **different** FSM without breaking client
- Code should focus only on portion of implementation relevant to ATM creation and ATM state management
- Deliverables:
    - Sketch of V6 ATM implementation