Human Computer Interaction

The MVC Pattern

Prof. Andrew D. Bagdanov

Dipartimento di Ingegneria dell'Informazione
Università degli Studi di Firenze
andrew.bagdanov AT unifi.it

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Outline

1. Upcoming
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3. The MVC Model
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Upcoming

Upcoming Stuff

This week

- Today: we will look at the MVC architectural pattern from a theoretical and hands-on perspective.
- Tomorrow: finally the next HCI laboratory session.
- Friday: NO CLASS.

Next Week

- Tuesday: past HCI projects, glue technologies and Latest and Greatest:

  Kokkalis et al., "MyriadHub: Efficiently Scaling Personalized Email Conversations with Valet Crowdsourcing." CHI, 2017.

- Wednesday: calculator lab.
- Friday: project brainstorming and intro to needfinding.

Overview

Overview

- In this lecture we will finally see a formal-ish introduction to the Model-View-Controller (MVC) paradigm.
- I will try to motivate each key concept with hands-on examples using our running example widgets.
- MVC is a technique you can apply to isolate key components of your GUI applications.
- It helps render these components reusable and future-proof.
- Note: MVC is only a paradigm (sometimes it's called an Architectural Pattern – it does not give a complete recipe for any and all applications.

Architectural Patterns

- Design patterns are reusable solutions for software development:
  - They are like templates you can use for creating applications.
  - They are typically grouped into three categories: creational patterns, structural patterns, and behavioral patterns.
- An architectural pattern is fundamental structural organization for software systems:
  - They define the overall shape and structure of software applications.
  - Architectural patterns are similar to software design pattern but have a broader scope.
- We will first look at the MVC architectural pattern, then we will look at some design patterns useful for HCI.

The MVC Model

MVC: Introduction

- The Model-View Controller (MVC) pattern lends itself quite well to the design of graphical user interfaces in general.
- Since I come from the generation that invented design patterns, I feel the need to sell them whenever I can.
- Patterns describes a proven solution to a recurring design problem, placing particular emphasis on the context and forces surrounding the problem, and the consequences and impact of the solution.
- There are many good reasons to use design patterns:
  1. They are proven: You tap the experience, knowledge and insights of developers who have used these patterns successfully in their own work.
  2. They are reusable: When a problem recurs, you don't have to invent a new solution: you follow the pattern and adapt it as necessary.
  3. They are expressive: Design patterns provide a common vocabulary of solutions, which you can use to express larger solutions succinctly.

MVC: Introduction

- It is important to remember that patterns do not guarantee success, and they should never be blindly applied.
- The programming language Smalltalk first defined the MVC concept in the 1970s.
- Since then, the MVC design idiom has become commonplace, especially in object-oriented systems.
- It has become especially commonplace in the world of web application design.
- In fact, it is illustrative to take a look at the massive number of web frameworks that are based on (or support) MVC.

MVC: Basic Components

- The MVC architectural pattern divides an interactive application into three components:
  - The Model contains the core data and related functionality.
  - Views display information to the user.
  - Controllers handle user input and mediate communication between views and model.
- Views and controllers together comprise the user interface.
- A change-propagation mechanism implemented by the Controller ensures consistency between the user interface and the Model.
- The most important separation is between presentation and application logic. The need for View/Controller split is less evident.
- MVC encompasses more of the architecture of an application than is typical for a design pattern, and the term architectural pattern for it may be more accurate.

MVC: Model

- The Model is a domain-specific representation of the information on which the application operates.
- The model is another name for the application logic layer (sometimes also called the domain layer).
- Application (or domain) logic adds meaning to raw data (e.g. calculating if today is the user's birthday, or the totals, taxes and shipping charges for shopping cart items).
- Many applications use a persistent storage mechanism (such as a database) to store data.
- MVC does not dictate anything about the resource management layer because it is understood to be encapsulated by the Model.
- The Model should contain all data and presentation-independent functionality that needs to operate on that data.

MVC: View

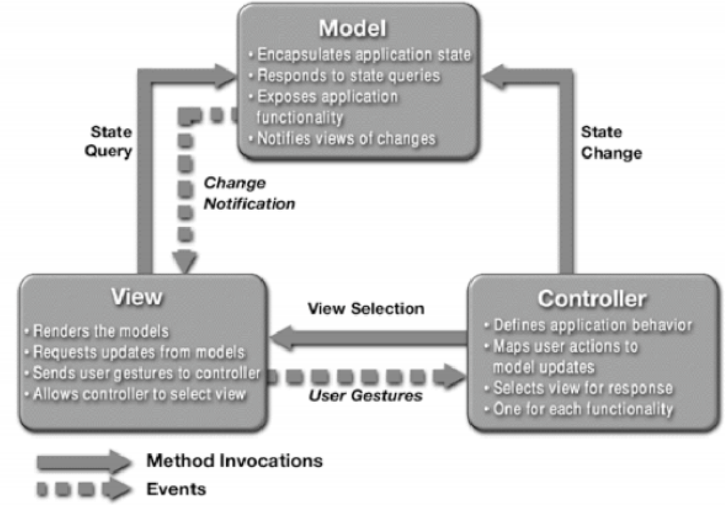
- A View Renders the Model (or some aspect of the Model) into a form suitable for interaction, typically a user interface element.
- MVC is often seen in web applications, where the View is the HTML page and the code which gathers dynamic data (from the Model) for the page.
- Note that there can be multiple Views of the same Model – that is one of the main advantages of separation of concerns offered by MVC.
- If the user changes the model via the Controller of one View, all other views dependent on this data should reflect the changes.
- The model therefore must somehow notify all views whenever its data changes, and Views must retrieve new data from the model and update the displayed information.

MVC: Controller

- Finally, a Controller processes and responds to events, typically user actions, and may invoke changes on the associated Model and Views.
- Often, each View has an associated Controller component (i.e. they are tightly coupled).
- It is often even debatable whether a View's Controller should even be a separate component.
- Controllers receive input (e.g. events encoding mouse movement, mouse button presses, or keyboard input).
- Events are translated to service requests for the Model and/or the associated View.
- The user interacts with the system solely through controllers.

MVC: A High-level Overview

- Here is a typical diagram of the MVC model in action:



Model
• Encapsulates application state
• Responds to state queries
• Exposes application functionality
• Notifies views of changes
State Query
Change Notification
State Change
View
• Renders the models
• Requests updates from models
• Sends user gestures to controller
• Allows controller to select view
View Selection
User Gestures
Controller
• Defines application behavior
• Maps user actions to model updates
• Selects view for response
• One for each functionality
Method Invocations
Events

MVC: A Typical Scenario

- Though MVC comes in a million scenarios, this is what a typical application might look like.
  1. The user (remember him?) interacts with the user interface in some way (e.g., user presses a button).
  2. A Controller handles the input event from the user interface, often via a registered handler or callback.
  3. The Controller accesses the Model, possibly updating it in a way appropriate to the user's action (e.g., Controller updates user's shopping cart).
  4. A View uses the Model to generate an appropriate user interface (e.g., View produces a screen listing the shopping cart contents).
  5. The View gets its own data from the Model and the Model has no direct knowledge of the View.
  6. Repeat.

An Illustrative Abstraction

An illustrative abstraction

- We will now have a look at an entertaining (and illustrative) presentation on MVC by Prof. Ron Fedkiw from Stanford University's course on mobile application design.
- [SWITCH PRESENTATION]

A Hands-on Example

A Hands-on Example

- Now let's go back to a version of our running example and see how we can adapt to to the MVC architecture.
- Recall that we had a ClickButton widget class, already defined in the KV language:

```
<CounterButton@Button>:
    counter: 0
    text: 'Clicks: {}'.format(self.counter)
    on_press: self.counter += 1
```

- In this simple example, we have in a single class: the Model (a integer counter), the View (a Kivy Button we inherit from) and Controller (intercepting mouse and property events to update View).
- With such simple state and update logic, it is hard to motivate the need for MVC.

A Hands-on Example

- But, what if we begin increasing the complexity of the update logic?

```
# Our class extends EventDispatcher so we can use properties.
class CounterModel(EventDispatcher):
    # The counter value
    counter = NumericProperty()
    interval = NumericProperty()

    # Constructor
    def __init__(self, initval=0, maxval=None):
        super(EventDispatcher, self).__init__()
        self.counter = initval
        self._maxval = maxval
        self._lastupdate = time.time()
        self.interval = 0.0

    # Method to bump the counter.
    def inc_counter(self):
        # This ensures the bound on counter if maxval not None.
        if not self._maxval or (self.counter < self._maxval):
            self.counter += 1
            now = time.time()
            self.interval = now - self._lastupdate
            self._lastupdate = now
```

A hands-on example

- We can imagine more complex Models, with multiple data types (structures), multiple items (lists, dicts).
- More importantly, we can imagine more Models which require more complex backends (e.g. a DBMS).
- In such cases, it is essential to isolate the internal structure and logic of the Model:
  - To keep the logic of presentation in Views uncluttered with data access and data update code.
  - To abstract access to Model data and render Views and Controllers independent of the actual storage model used by the Model.
  - To make it possible for multiple Views to share the same Model.
- This example is clearly artificial, but let's pretend. . .

A hands-on example

- Now let's define two Views in the KV design language (Kivy `Buttons` in our case):

```
<CounterButton@ButtonWithModel>:
    text: 'Clicks: {}'.format(self.model.counter)
    on_press: self.model.inc_counter()

<CounterIntervalButton@ButtonWithModel>:
    text: 'Clicks: {} [{:.2f}]'.format(self.model.counter,
                                       self.model.interval)
    on_press: self.model.inc_counter()
```

- These Views assume they have an associated model (which should probably be accessed through a singleton).
- They are not dependent on the Model, but on the model interface.
- We are free to change the implementation of counter as much as we like.

A hands-on example

- Now we can instantiate and start using these new MVC components.
- Note, this is all technically Controller code:

```
# Simple, single button app.
def single_button():
    root = Factory.CounterButton(CounterModel())
    runTouchApp(root)

# Simple, both button types displayed.
def both_buttons():
    left = Factory.CounterButton(CounterModel())
    right = Factory.CounterIntervalButton(CounterModel())
    top = BoxLayout(orientation='horizontal')
    top.add_widget(left)
    top.add_widget(right)
    runTouchApp(top)
```

A hands-on example

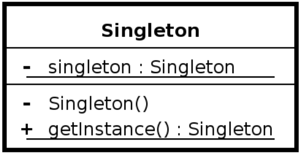
- With the new Model implementation, we can share the same Model instance across multiple views:

```
# Both button types, shared model.
def shared_buttons():
    left = Factory.CounterButton(CounterModel())
    right = Factory.CounterIntervalButton(left.model)
    top = BoxLayout(orientation='horizontal')
    top.add_widget(left)
    top.add_widget(right)
    runTouchApp(top)
```

Design Patterns for HCI

The Singleton Pattern

- The singleton Pattern is a (somewhat) common creational design pattern in GUI programming.
- We use a singleton when there needs to be one and only one instance of a given class.
- It is useful for modeling unique resources or to coordinate actions across subsystems.
- For example, when implementing a model in an MVC architecture.
- It is also my favorite pattern:



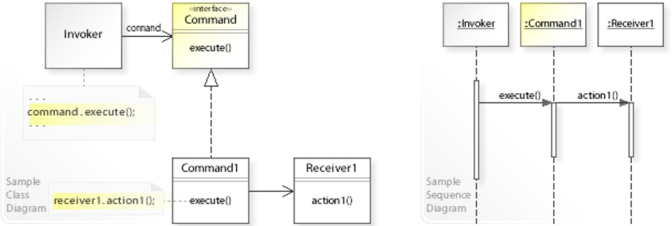
Singleton

- singleton : Singleton

- Singleton()
+ getInstance() : Singleton

The Command Pattern

- Complex Controllers often use the command pattern.
- Command is a behavioral pattern that encapsulates a function invocation (e.g. a method call) into an object that can used to invoke the function at a later time.
- This helps encapsulate actions and simplify extension and composability.
- Examples: multi-level undo, macro recording, progress bars, logging.



```
...
command.execute();
...
```

```
receiver1.action1();
```

Command Pattern: Show me the code

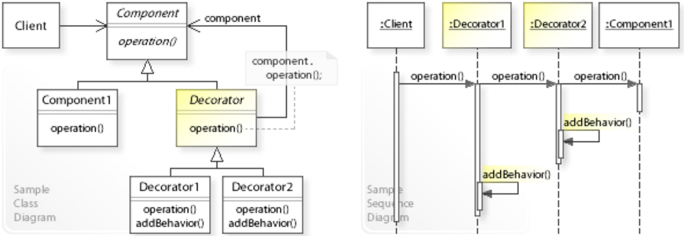
- And example use of Command:

```
class MoveFileCommand(object):
    def __init__(self, src, dest):
        self.src = src
        self.dest = dest
        os.rename(self.src, self.dest)
    def undo(self):
        os.rename(self.dest, self.src)

undo_stack = []
undo_stack.append(MoveFileCommand('foo.txt', 'bar.txt'))
undo_stack.append(MoveFileCommand('bar.txt', 'baz.txt'))
# foo.txt is now renamed to baz.txt
undo_stack.pop().undo() # Now it's bar.txt
undo_stack.pop().undo() # and back to foo.txt
```

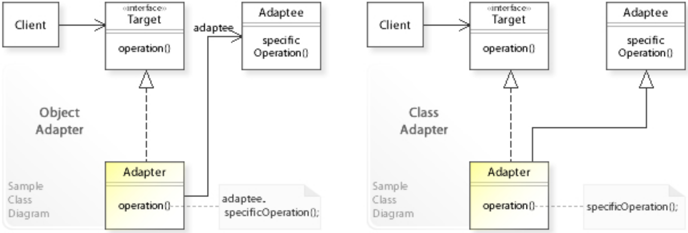
The Decorator Pattern

- The Decorator Pattern is a structural design pattern that allows us to dynamically (or statically, if that's your thing) extend functionality of an existing class.
- An example of this are widget behaviors: we can add the `ButtonBehavior` to any widget class to make it behave like a button.



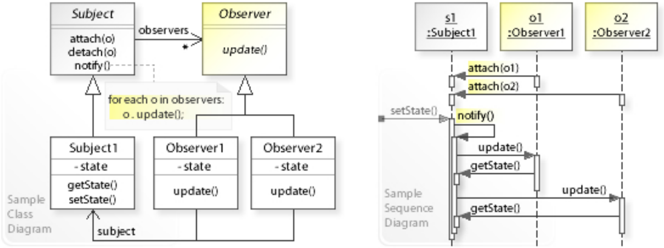
The Adapter Pattern

- The Adapter Pattern is a structural design pattern that allows us to use an existing interface as another.
- This is useful to adapt an existing class for use with a different interface.
- In GUI frameworks this is used to make scroll lists more generic: we adapt an arbitrary collection for use as a `ScrollListItem`.



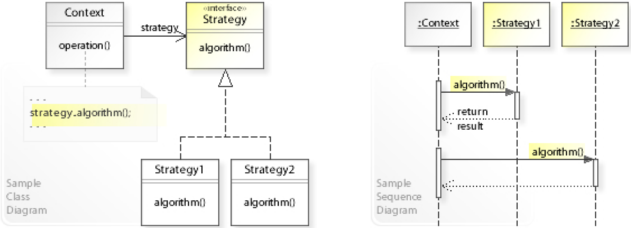
The Observer Pattern

- The Observer Pattern is a behavioral design pattern that allows us to establish a publish/subscribe interface for state-change notification.
- We have already seen examples of this with Kivy properties.
- It is an essential component of GUI and event-driven programming.



The Strategy Pattern

- The Strategy Pattern is a behavioral design pattern that allows us to select an algorithm to execute at runtime.
- With it we can define a family of algorithms which are interchangeable (e.g. mergesort, quicksort, and radix sort).
- At runtime we can select which to use based on context.
- Example: Kivy layouts.



Summary

Summary

- MVC are architectural design patterns that promote reusability and extensibility through structured separation of concerns.
- We saw through examples how even simple Models can be made more reusable through abstraction of the data backend.
- These models can support multiple Views, and can even be shared among multiple Views simultaneously.
- As with all patterns, MVC should not be applied blindly, but always with a critical eye for elegance, readability, and maintainability.
- Note that in modern GUI frameworks, many aspects traditionally handled by Control components is handled automatically by event processing subsystems.
- Also note that many GUI frameworks (like Kivy) directly support MVC organization through their underlying architecture (see Homework).

Homework

Homework

Exercise 12.1: extending the example

Read the Kivy documentation on Adapters. This is a class in Kivy designed to help mediate communication between Models and Views. Implement a new View that visualized our existing `CounterModel` Model from this lesson as a ListView. The `ListView` should display the click count, and the interval.

Exercise 12.2: extending the example (again)

Extend the view implemented in the previous exercise (and the CounterModel, probably) to include a Reset button in the visualization of the `ListView` of `CounterModel`.

Exercise 12.3: reset functionality.

Implement the required functionality for the reset button associated with each `ListItem` in the previous exercise. NOTE: This will require extensions to the model.