Principles of Software Construction: Objects, Design and Concurrency

Design Case Study: GUI with Swing

15-214

toad

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Design Goals - Summary

- 5 design goals
  - Design for division of labor
  - Design for understandability and maintenance
  - Design for change
  - Design for reuse
  - Design for robustness
- 5 design strategies
  - Explicit interfaces (clear boundaries)
  - Information hiding(hide likely changes)
  - Low coupling (reduce dependencies)
  - High cohesion (one purpose per class)
  - Low repr. gap (align requirements and impl.)
- 3 GRASP patterns
  - Information Expert
  - Creator
  - Controller

Learning Goals

- Understanding event-based programming
- Understanding design patterns in GUIs
  - Strategy pattern
  - Observer pattern
  - Composite pattern
  - Decorator pattern
  - Template method pattern
  - Façade pattern
  - Model-view-controller pattern

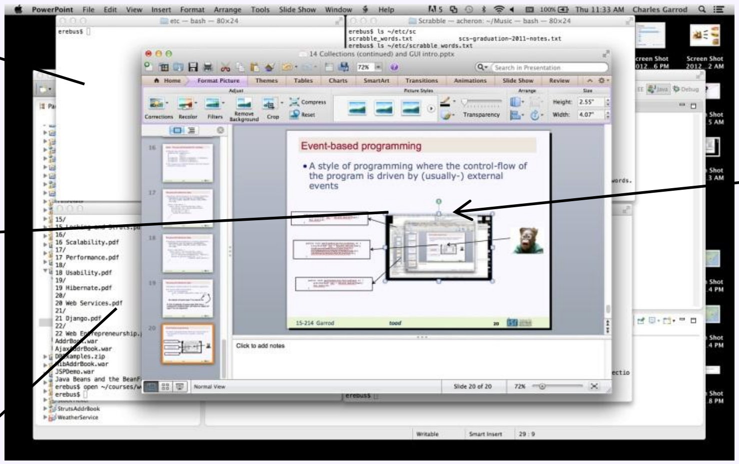
Event-based programming

- Style of programming where control-flow is driven by (usually external) events

```
public void performAction(ActionEvent e) {
    List<String> lst = Arrays.asList(bar);
    foo.peek(42)
}
```

```
public void performAction(ActionEvent e) {
    bigBloatedPowerPointFunction(e);
    withANameSoLongIMadeItTwoMethods(e);
    yesIKnowJavaDoesntWorkLikeThat(e);
}
```

```
public void performAction(ActionEvent e) {
    List<String> lst = Arrays.asList(bar);
    foo.peek(40)
}
```



PowerPoint File Edit View Insert Format Arrange Tools Slide Show Window Help
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etc — bash — 80×24
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14 Collections (continued) and GUI intro.pptx
Home Format Picture Themes Tables Charts SmartArt Transitions Animations Slide Show Review
Corrections Recolor Filters Remove Background Crop Compress Reset Transparency
Height: 2.55" Width: 4.07"
Click to add notes
Normal View Slide 20 of 20 72%
Writable Smart Insert 29 : 9

```
erebus$ ls ~/etc/sc
scrabble_words.txt         scs-graduation-2011-notes.txt
erebus$ ls ~/etc/scrabble_words.txt
```

```
15/
16/
16 Scalability.pdf
17/
17 Performance.pdf
18/
18 Usability.pdf
19/
19 Hibernate.pdf
20/
20 Web Services.pdf
21/
21 Django.pdf
22/
22 Web Entrepreneurship.
AddrBook.war
AjaxAddrBook.war
DBExamples.zip
HibAddrBook.war
JSPDemo.war
Java Beans and the BeanF
erebus$ open ~/courses/w
erebus$
```

Event-based programming

- A style of programming where the control-flow of the program is driven by (usually-) external events

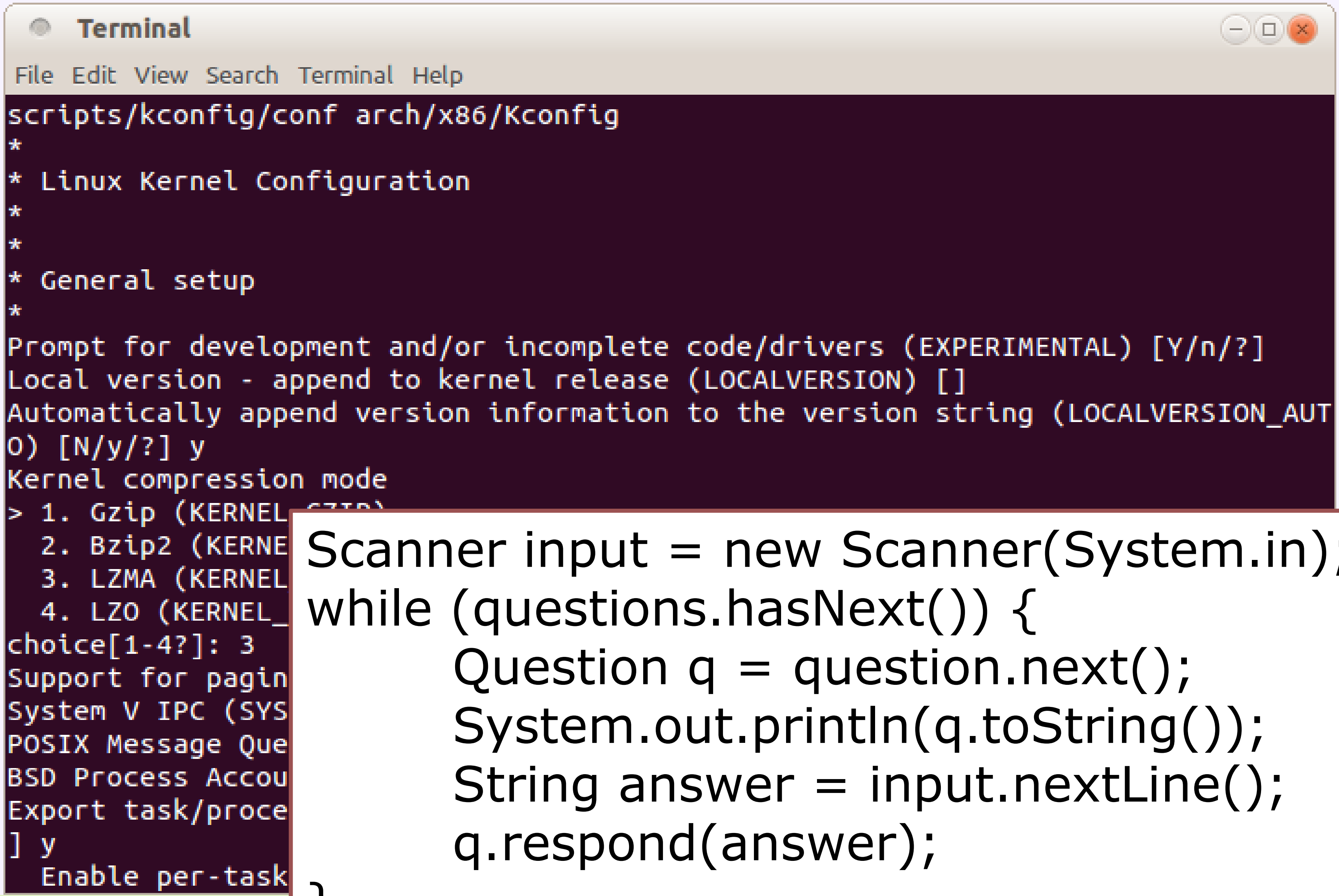
15-214 Garrod toad 20

Events in GUIs

- User clicks a button, presses a key
- User selects an item from a list, an item from a menu, expands a tree
- Mouse hovers over a widget, focus changes
- Scrolling, mouse wheel turned
- Resizing a window, hiding a window
- Drag and drop

- A package arrives from a web service, connection drops, …
- System shutdown, …

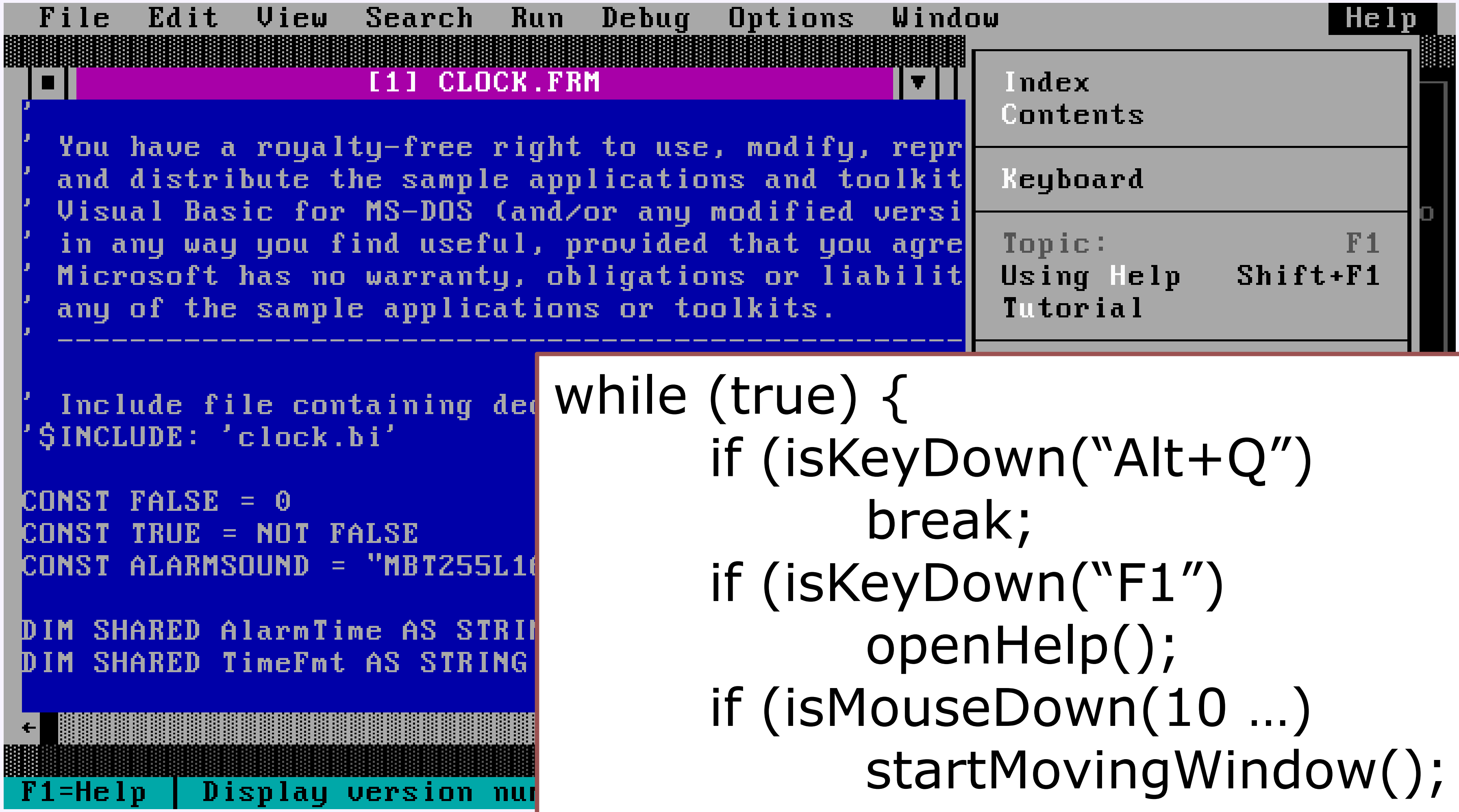
Command-Line Interfaces



```
scripts/kconfig/conf arch/x86/Kconfig
*
* Linux Kernel Configuration
*
*
* General setup
*
Prompt for development and/or incomplete code/drivers (EXPERIMENTAL) [Y/n/?]
Local version - append to kernel release (LOCALVERSION) []
Automatically append version information to the version string (LOCALVERSION_AUT
O) [N/y/?] y
Kernel compression mode
> 1. Gzip (KERNEL
  2. Bzip2 (KERNE
  3. LZMA (KERNEL
  4. LZO (KERNEL_
choice[1-4?]: 3
Support for pagin
System V IPC (SYS
POSIX Message Que
BSD Process Accou
Export task/proce
] y
  Enable per-task
```

```
Scanner input = new Scanner(System.in);
while (questions.hasNext()) {
        Question q = question.next();
        System.out.println(q.toString());
        String answer = input.nextLine();
        q.respond(answer);
}
```

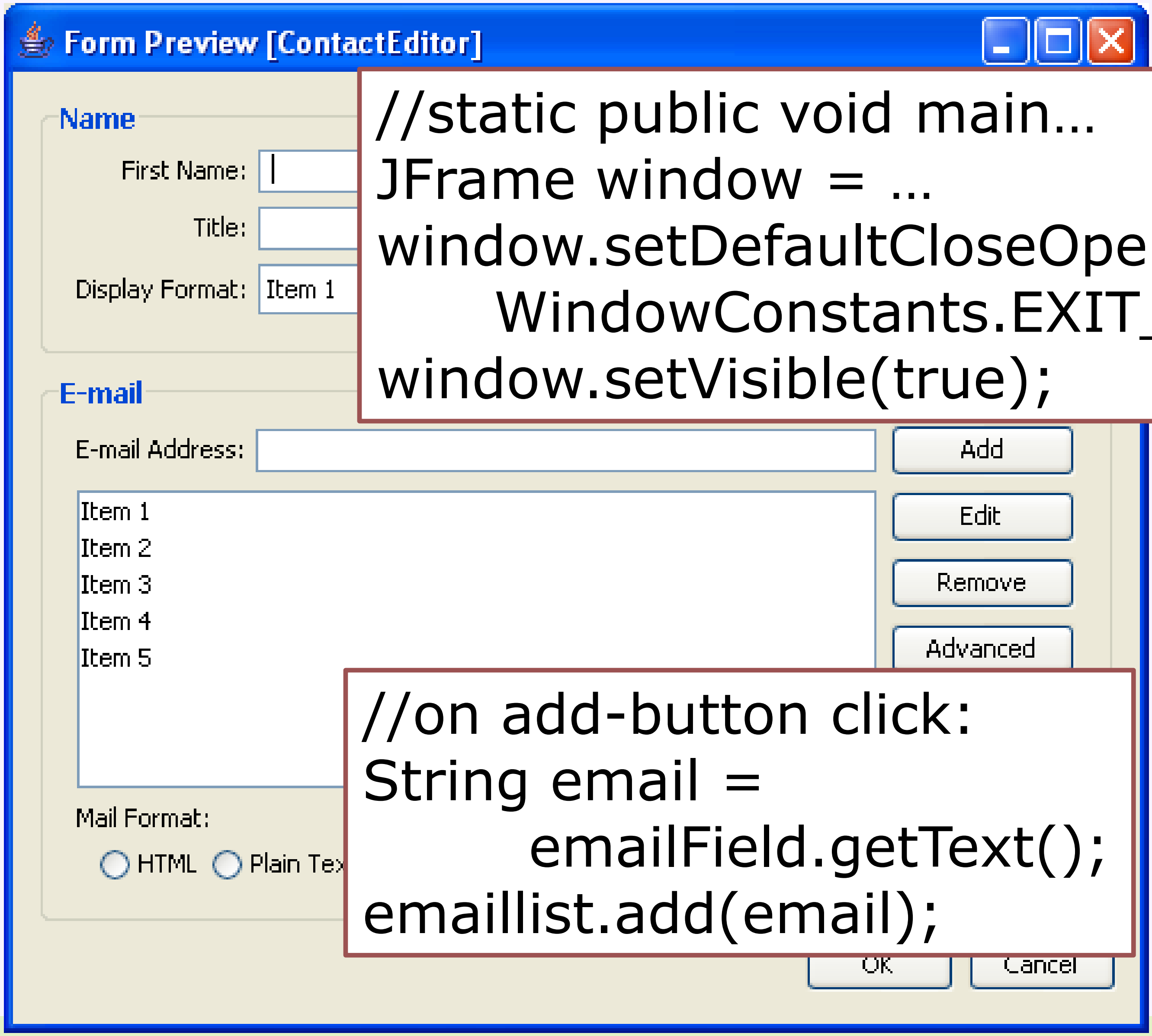
Pre-Event GUIs



```
'
' You have a royalty-free right to use, modify, repr
' and distribute the sample applications and toolkit
' Visual Basic for MS-DOS (and/or any modified versi
' in any way you find useful, provided that you agre
' Microsoft has no warranty, obligations or liabilit
' any of the sample applications or toolkits.
'
  -----------------------------------------------

' Include file containing dec
'$INCLUDE: 'clock.bi'

CONST FALSE = 0
CONST TRUE = NOT FALSE
CONST ALARMSOUND = "MBT255L16

DIM SHARED AlarmTime AS STRIN
DIM SHARED TimeFmt AS STRING
```

```
while (true) {
        if (isKeyDown("Alt+Q")
                break;
        if (isKeyDown("F1")
                openHelp();
        if (isMouseDown(10 …)
                startMovingWindow();
        …
}
```

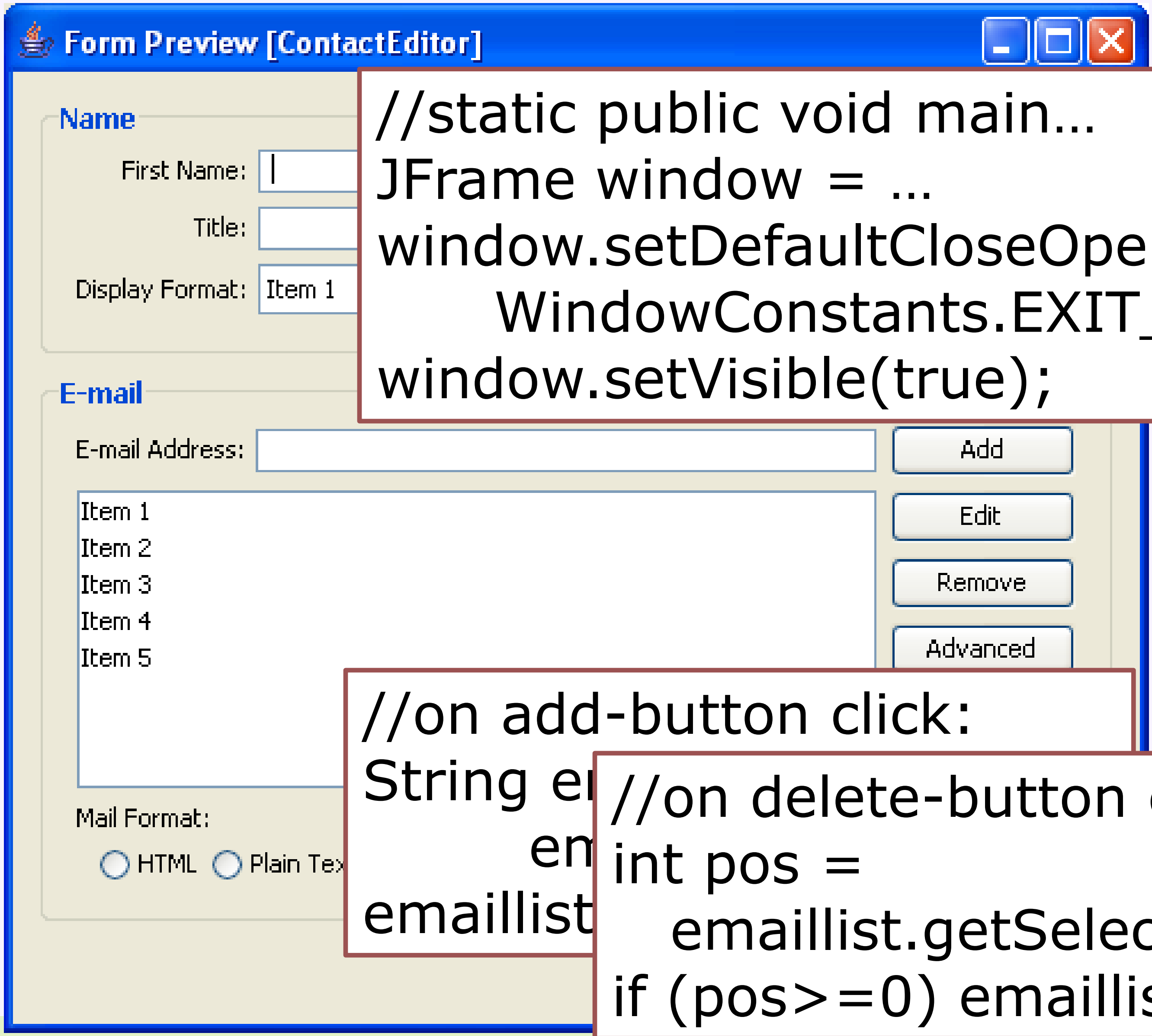
Event-based GUIs



```
//static public void main…
JFrame window = …
window.setDefaultCloseOperation(
        WindowConstants.EXIT_ON_CLOSE);
window.setVisible(true);
```

```
//on add-button click:
String email =
        emailField.getText();
emaillist.add(email);
```

Event-based GUIs

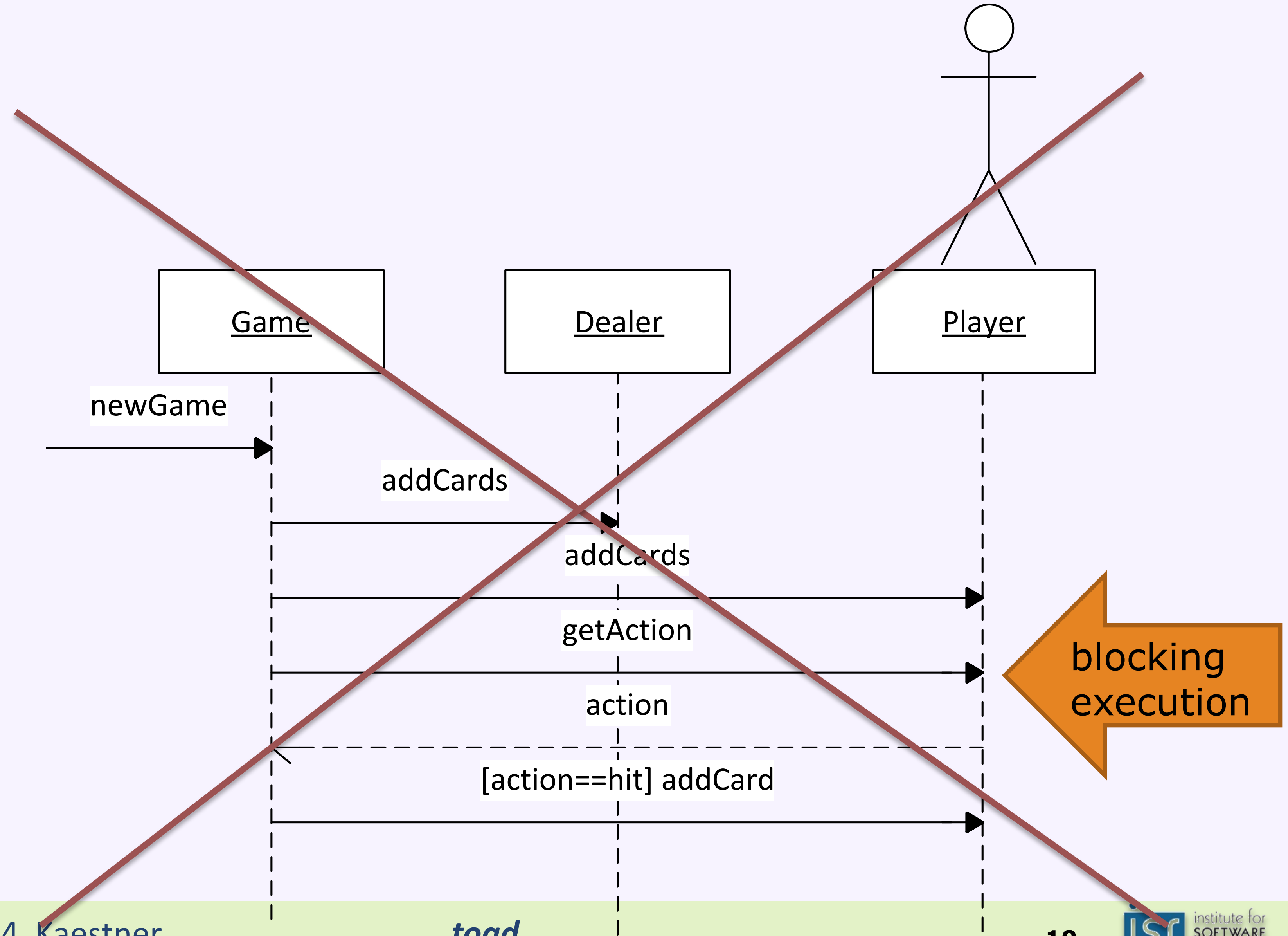


```
//static public void main…
JFrame window = …
window.setDefaultCloseOperation(
      WindowConstants.EXIT_ON_CLOSE);
window.setVisible(true);
```

```
//on add-button click:
String em
         em
emaillist
```

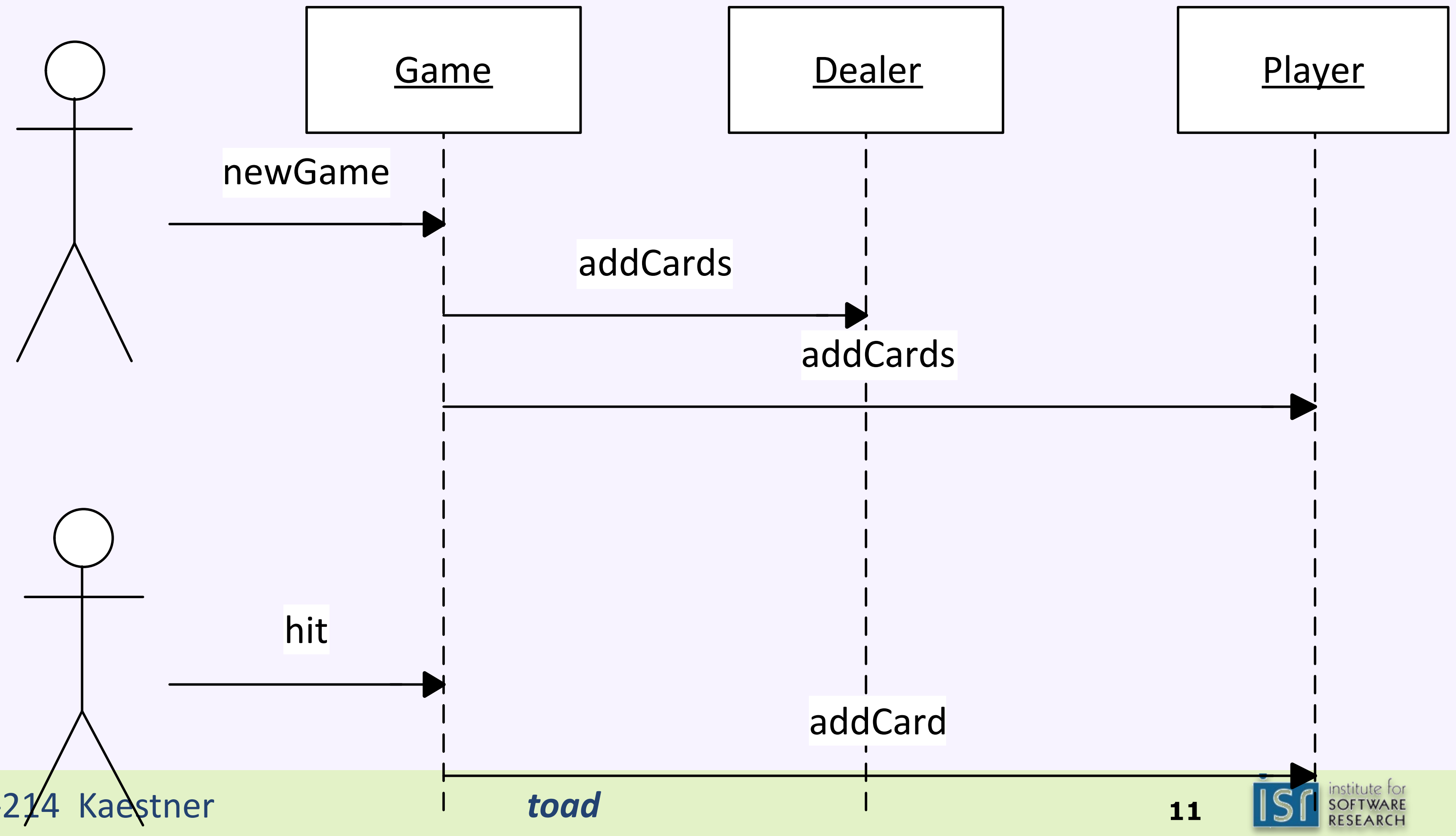
```
//on delete-button click:
int pos =
   emaillist.getSelectedItem();
if (pos>=0) emaillist.delete(pos);
```

(Blocking) Interactions with Users



Interactions with Users through Events

- Do not wait for user response, react to event
- Here: Two interactions to separate events:

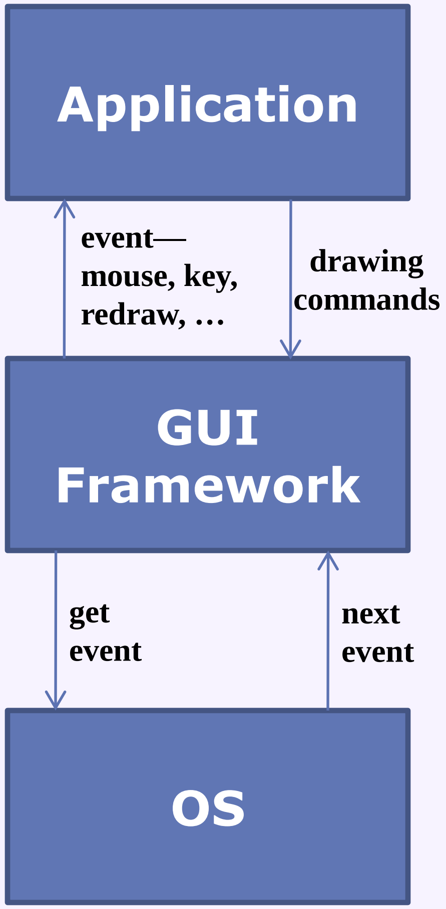


Event-Based GUI Model

- The program has no main loop! Continues executing even after main method ends
- Program is idle after start until called for events
- The operating system / GUI framework processes all keyboard/mouse/… events
- Only few events are relevant for application
- Every widget may react to its own events
- Program/widgets may register callbacks to react to specific events
- Program ends by calling specific API, not when the main method finishes executing

Reacting to events from GUI framework

- Setup phase
  - Describe how the GUI window should look
  - Use libraries for windows, widgets, and layout
  - Embed specialized code for later use
  - Register callbacks
- Execution
  - Framework gets events from OS
    - Raw events: mouse clicks, key presses, window becomes visible, etc.
  - Framework processes events
    - Click at 10,40: which widget?
    - Resize window: what to re-layout and redraw?
  - Triggers callback functions of corresponding widgets (if registered)



Example: RabbitWorld GUI

- …hw2.lib.ui.WorldUI.main()
  - Creates a top-level window
  - Creates a WorldUI to go in it
  - Sets some parameters
  - Makes the window (and its contents) visible

- …hw2.lib.ui.WorldPanel.paintComponent()
  - Called when the OS needs to show the WorldPanel (part of WorldUI)
    - Right after the window becomes visible
  - super.paintComponent() draws a background
  - ImageIcon.paintIcon(…) draws each item in the world

Let's look at the code…

GUI Frameworks in Java

- AWT
  - Native widgets, only basic components, dated
- Swing
  - Java rendering, rich components
- SWT + JFace
  - Mixture of native widgets and Java rendering; created for Eclipse for faster performance
- Others
  - Apache Pivot, SwingX, JavaFX, …
- Different in their specific designs, but similar overall strategies and concepts

Swing

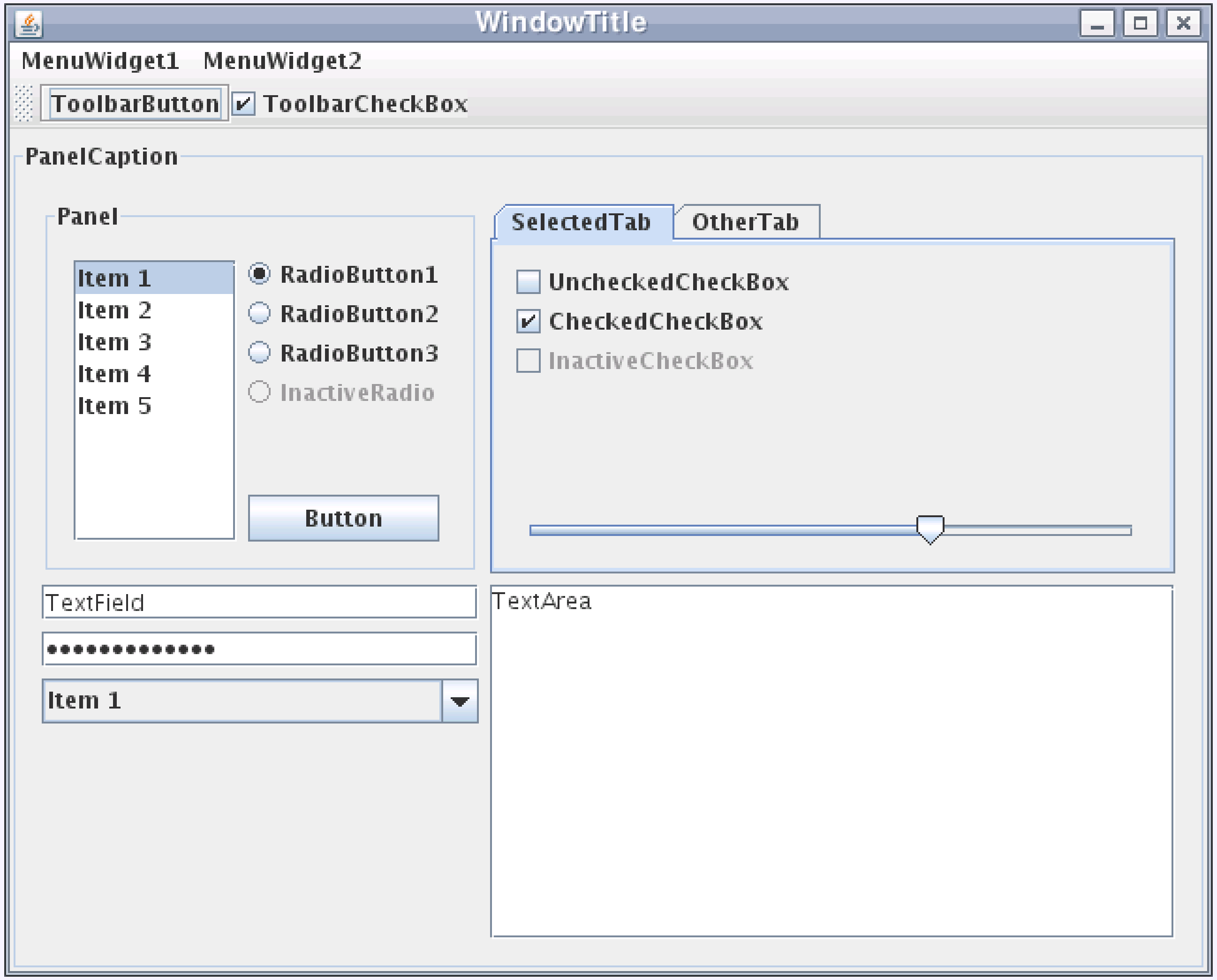
JFrame

JPanel

JButton

JTextField

…



Swing has lots of widgets

- JLabel
- JButton
- JCheckBox
- JChoice
- JRadioButton
- JTextField
- JTextArea
- JList
- JScrollBar
- … and more

- JFrame is the Swing Window
- JPanel (aka a pane) is the container to which you add your components (or other containers)

To create a simple Swing application

- Make a Window (a JFrame)
- Make a container (a JPanel)
  - Put it in the window
- Add components (Buttons, Boxes, etc.) to the container
  - Use layouts to control positioning
  - Set up observers (a.k.a. listeners) to respond to events
  - Optionally, write custom widgets with application-specific display logic
- Set up the window to display the container

- Then wait for events to arrive…

Reacting to Events

Creating a Button

```
//static public void main…
JFrame window = …

JPanel panel = new JPanel();
window.setContentPane(panel);

JButton button = new JButton(“Click me”);
button.addActionListener(new ActionListener() {
        public void actionPerformed(ActionEvent e) {
                System.out.println(“Button clicked”);
        }
});
panel.add(button);

window.setVisible(true);
```

panel to hold the button

callback function implements ActionListener interface

register callback function

Action Listeners

- Listeners are objects with callback functions
- Listeners can be registered with widgets
- Widgets call all registered widgets if event occurs

```
interface ActionListener {
        void actionPerformed(ActionEvent e);
}
```

```
class ActionEvent {
        int when;
        String actionCommand;
        int modifiers;
        Object source();
        int id;
        …
}
```

Action Listeners

- Listeners are objects with callback functions
- Listeners can be registered with widgets
- Widgets call all registered widgets if event occurs

```
interface ActionListener {
        void actionPerformed(ActionEvent e);
}
```

```
class ActionEvent {
                                            nd;
```

```
class AbstractButton extends JComponent {
        private List<ActionListener> listeners;
        public void addActionListener(ActionListener l) {
                listeners.add(l);
        }
        protected void fireActionPerformed(ActionEvent e) {
                for (ActionListener l: listeners)
                        l.actionPerformed(e);
        }
}
```

Alternative Button

```
class MyButton extends JButton {
   public MyButton() { super(“Click me”); }
   @Override
   protected void fireActionPerformed(ActionEvent e) {
         super.fireActionPerformed(e);
         System.out.println(“Button clicked”);
   }
}

//static public void main…
JFrame window = …
JPanel panel = new JPanel();
window.setContentPane(panel);
panel.add(new MyButton());
window.setVisible(true);
```

Design Discussion

- Button implementation should be reusable
  - but differ in button label
  - and differ in event handling
  - multiple independent clients might be interested in observing events
  - basic button cannot know what to do
- Decoupling action of button from button implementation itself
- Inheritance simple form to specialize buttons (second example)
- Listeners are separate objects, fulfilling an interface (first example)
  - multiple listeners possible
  - multiple buttons can share same listener

```
JButton btnNewButton = new JButton("New
button");

btnNewButton.addActionListener(new
ActionListener() {
        public void actionPerformed(ActionEvent e) {
                counter.inc();
        }
});

btnNewButton.addActionListener(new
ActionListener() {
        public void actionPerformed(ActionEvent e) {
                JOptionPane.showMessageDialog(null,
                        "button clicked", "alert",
                        JOptionPane.ERROR_MESSAGE);
        }
});
```

```
class MyButton extends JButton {
        Counter counter;
        public MyButton() {
                … setTitle…
        }
        protected void fireActionPerformed(ActionEvent e)
                counter.inc();
        }
}

JButton btnNewButton = new MyButton();
panel.add(btnNewButton);
```

```
public class ActionListenerPanel extends JPanel
                                  implements ActionListener {
        public ActionListenerPanel() { setup(); }
        private void setup() {
                button1 = new JButton(”a”);
                button1.addActionListener(this);
                button2 = new JButton(“b”);
                button2.addActionListener(this);
                add(button1); add(button2);
        }
        public void actionPerformed(ActionEvent e) {
                if(e.getSource()==button1)
                        display.setText( BUTTON_1 );
                else if(if(e.getSource()==button1) …
        }
        …
}
```

```
public class ActionListenerPanel extends JPanel
                                    implements ActionListener {
        public ActionListenerPanel() { setup(); }
        private void setup() {
                button1 = new JButton(”a”);
                button1.addActionListener(this);
                button2 = new JButton(“b”);
                button2.addActionListener(this);
                add(button1); add(button2);
        }
        public void actionPerformed(ActionEvent e) {
```

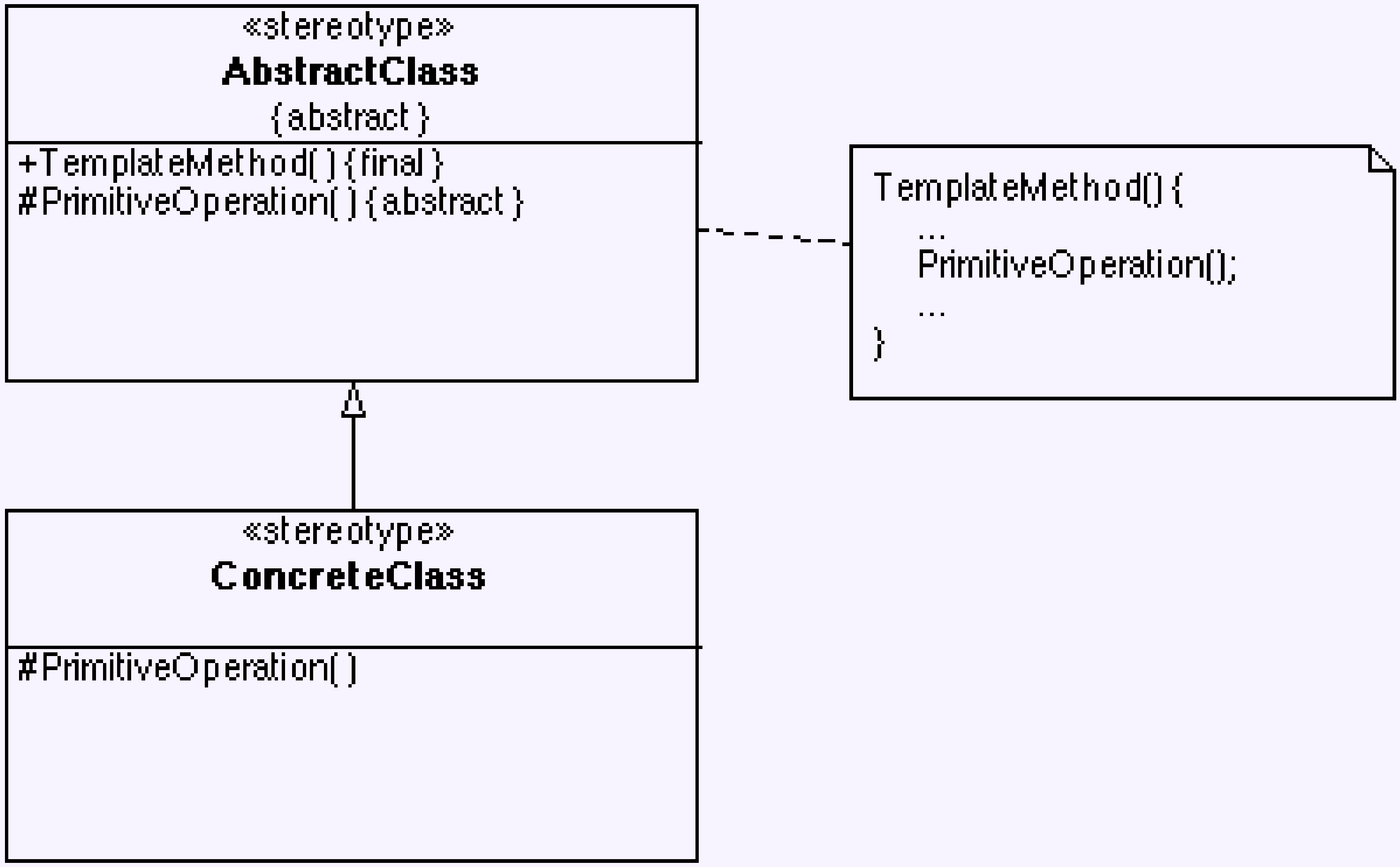
Cohesion?

Class responsibilities include (1) building the display, (2) wiring buttons and listeners, (3) mapping events to proper response, (4) perform proper response

Consider separating out event handling with different listeners

```
}
```

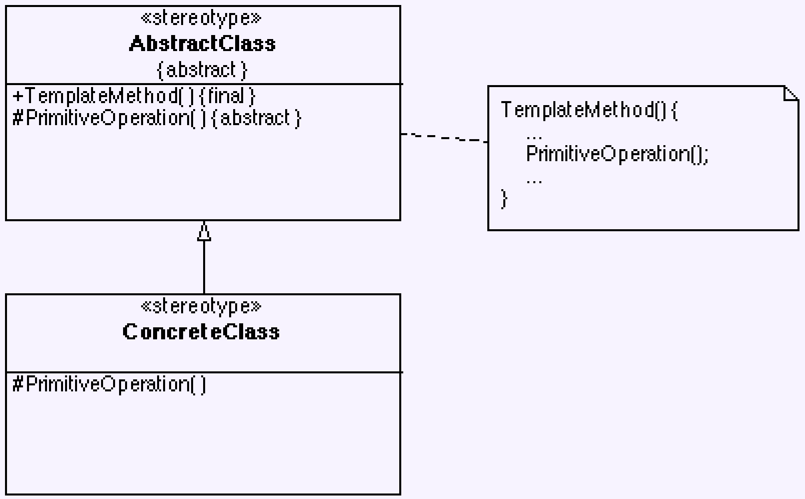
The *Template Method* design pattern



```
TemplateMethod() {
    …
    PrimitiveOperation();
    …
}
```

The *Template Method* design pattern

- Applicability
  - When an algorithm consists of varying and invariant parts that must be customized
  - When common behavior in subclasses should be factored and localized to avoid code duplication
  - To control subclass extensions to specific operations
- Consequences
  - **Code reuse**
  - Inverted "Hollywood" control: don't call us, we'll call you
  - Ensures the invariant parts of the algorithm are not changed by subclasses

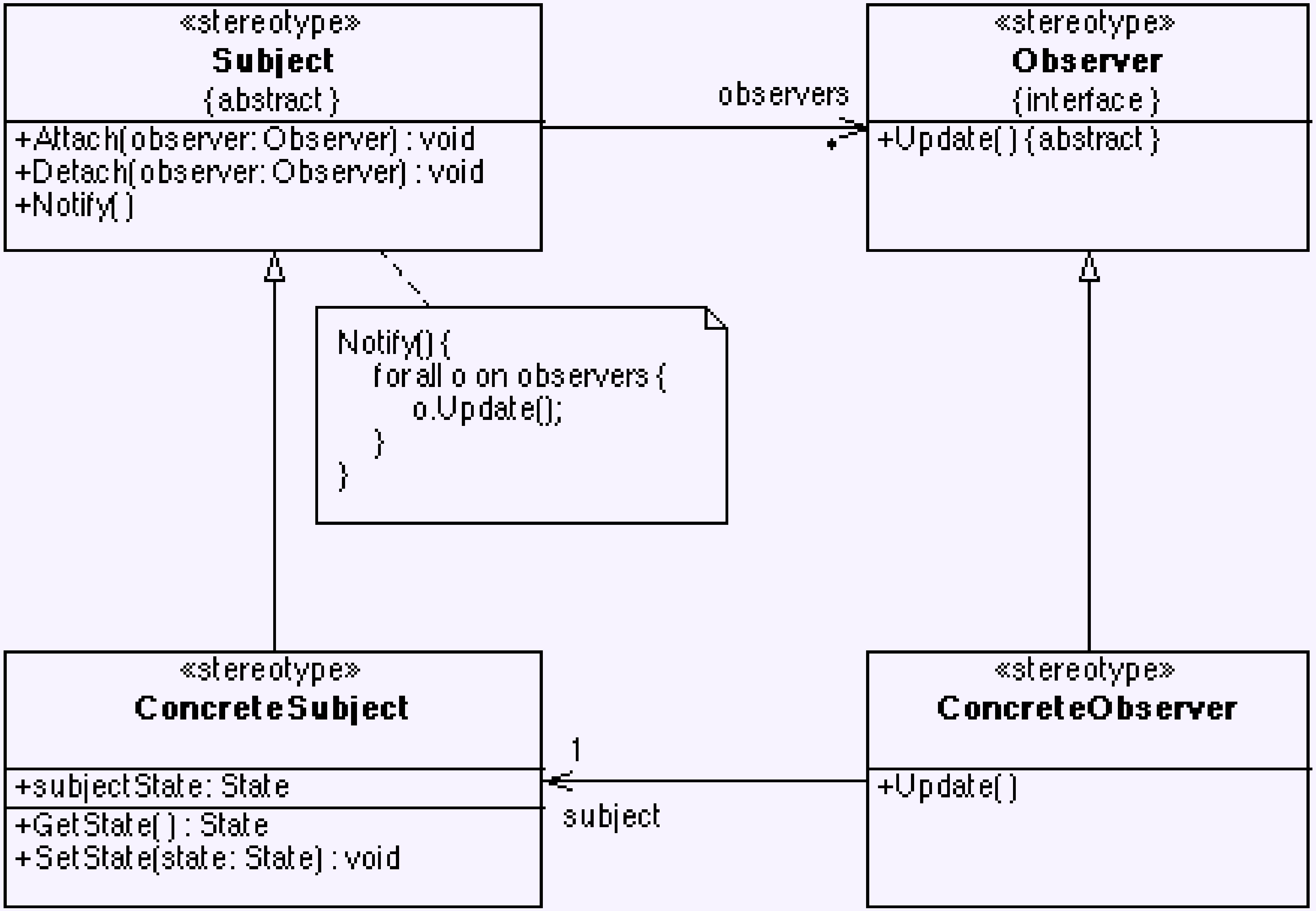


You may have used this in your virtual world

Template Method in JButton

- JButton has some behavior of how to handle events
  - eg drawing the button pressed while mouse down
- Some behavior remains undefined until later -> abstract method
  - In this case, default implementation of fireActionEvent already exists
- Template method provides specific extension point within larger shared computation

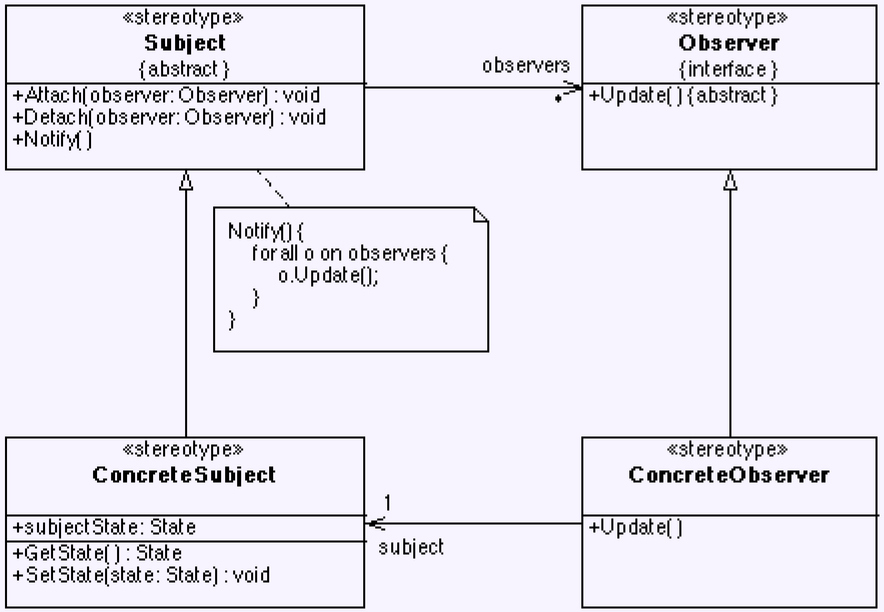
The *Observer* design pattern



```
Notify() {
    for all o on observers {
        o.Update();
    }
}
```

The *Observer* design pattern

- Applicability
  - When an abstraction has two aspects, one dependent on the other, and you want to reuse each
  - When change to one object requires changing others, and you don't know how many objects need to be changed
  - When an object should be able to notify others without knowing who they are
- Consequences
  - **Loose coupling** between subject and observer, enhancing **reuse**
  - Support for broadcast communication
  - Notification can lead to further updates, causing a cascade effect

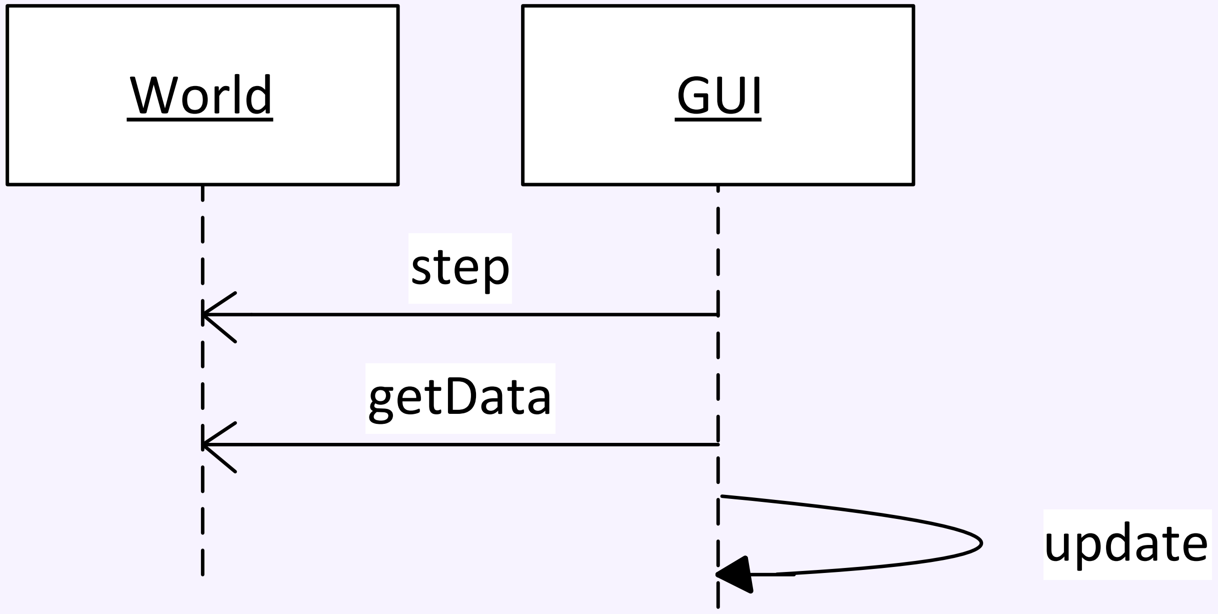


Swing has lots of event listener interfaces:

- ActionListener
- AdjustmentListener
- FocusListener
- ItemListener
- KeyListener
- MouseListener
- TreeExpansionListener
- TextListener
- WindowListener
- …and on and on…

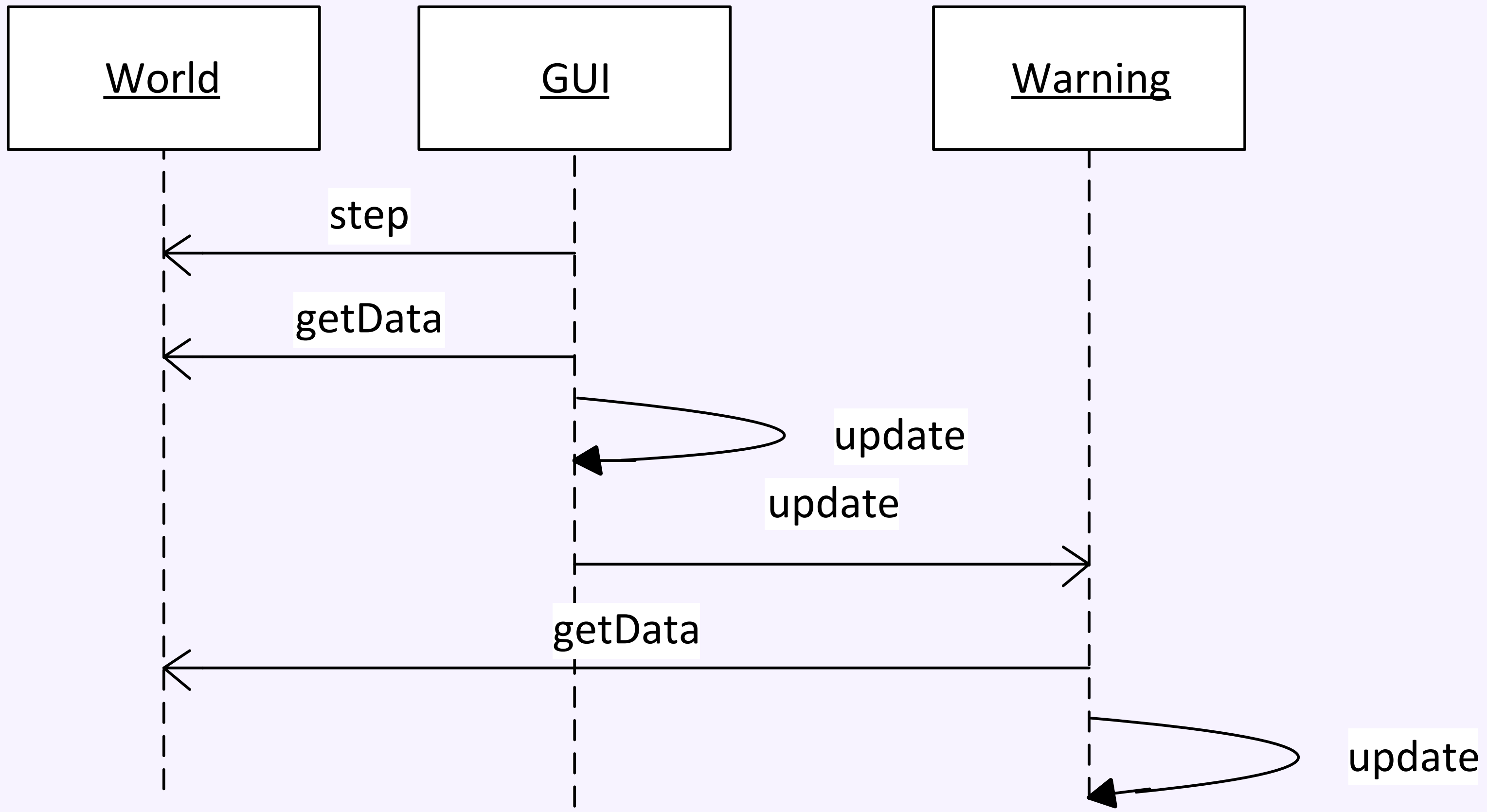
Observer Pattern between Data Model and GUI

- Consider Virtual World:
  - World stores all items
  - GUI shows items
  - GUI triggers new behavior in world
  - When should the GUI update the picture?



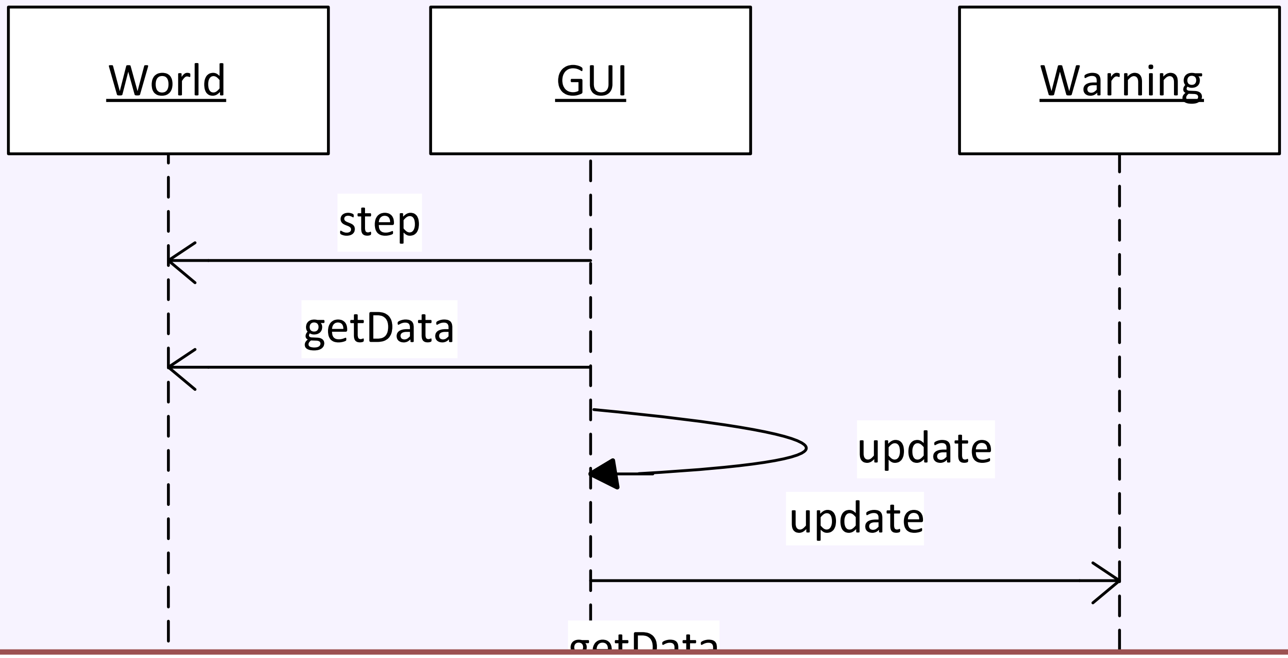
Observer Pattern between Data Model and GUI

- What if we add a warning field to the GUI that alerts if rabbits are about to die out?



Observer Pattern between Data Model and GUI

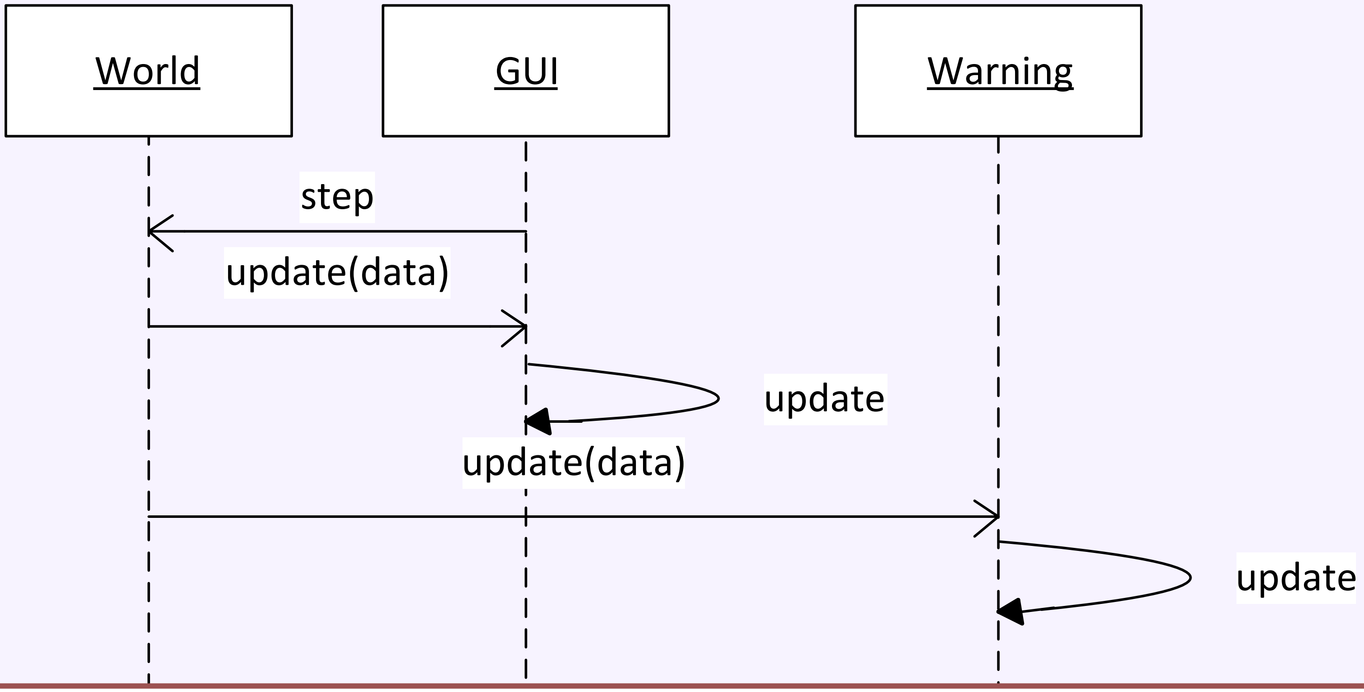
- What if we add a warning field to the GUI that alerts if rabbits are about to die out?



All control within the GUI.
What if the World changes for other reasons not triggered by the GUI?

Observer Pattern between Data Model and GUI

- Alternative Design: Let the World tell the GUI if something happened

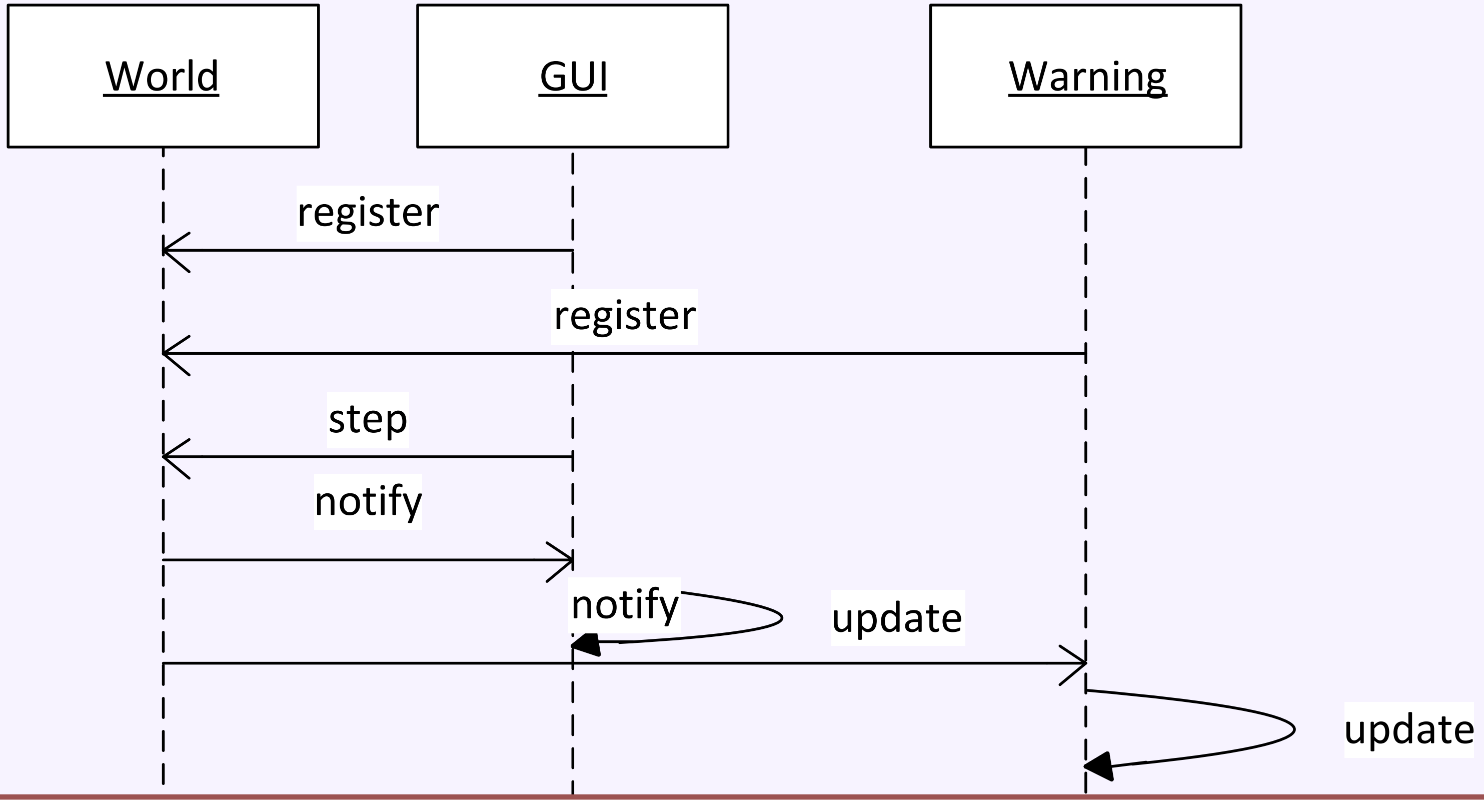


Inflexible to add new object to update (always requires change to the World)

Coupling from World to specific GUI implementations

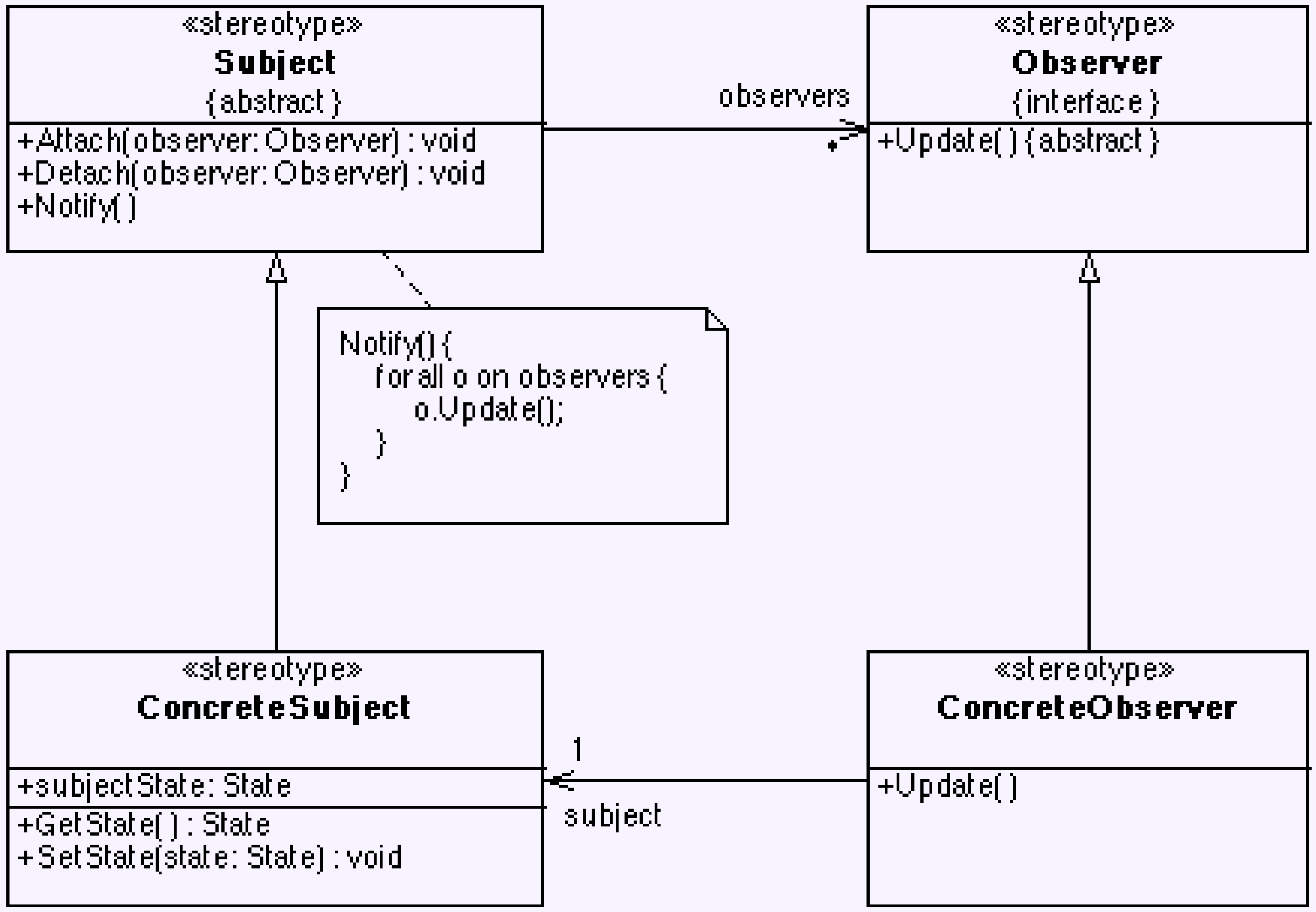
Observer Pattern between Data Model and GUI

- Observer Design: Let the world tell anybody interested about updates



Observer pattern decouples core implementation from GUI. Explicit interfaces, lower coupling, better reuse, easier to change and extend, …

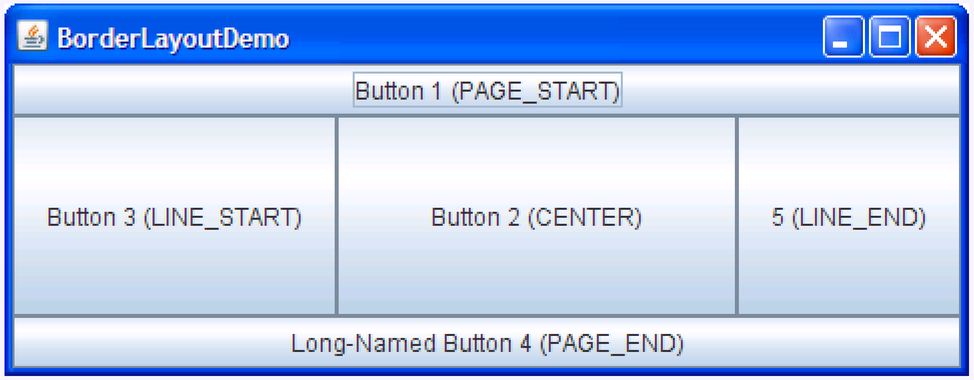
The *Observer* design pattern

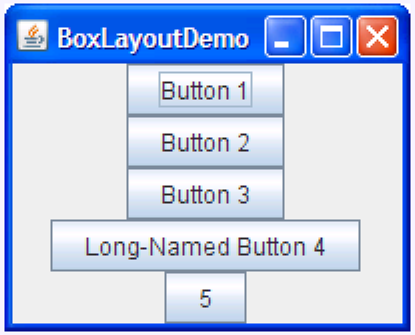


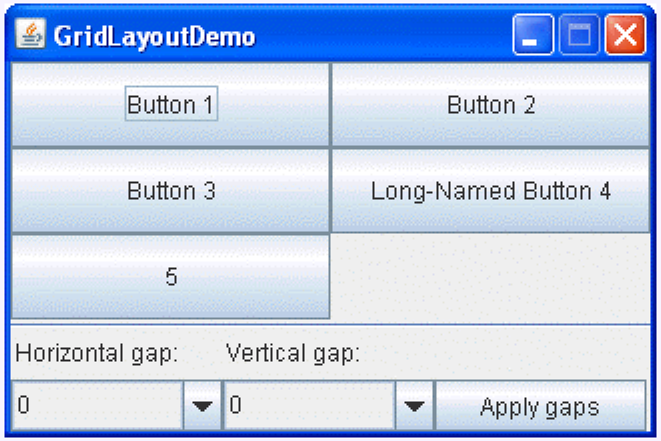
```
Notify() {
    for all o on observers {
        o.Update();
    }
}
```

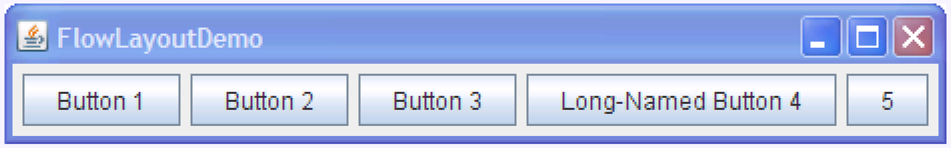
Layout of Widgets

Swing Layout Manager









see http://docs.oracle.com/javase/tutorial/uiswing/layout/visual.html

A naïve Implementation

- Hard-code layout algorithms

```
class JPanel {
    protected void doLayout() {
        switch(getLayoutType()) {
            case BOX_LAYOUT: adjustSizeBox(); break;
            case BORDER_LAYOUT: adjustSizeBorder(); break;
            ...
        }
    }
    private adjustSizeBox() { … }
}
```

- A new layout requires changing or overriding JPanel

Layout Manager

- A panel has a list of children
- Different layouts possible
  - List of predefined layout strategies
  - Own layouts possible
- Every widget has preferred size
- Delegate specific layout to a separate class implementing an explicit interface
  - Use polymorphism for extensibility

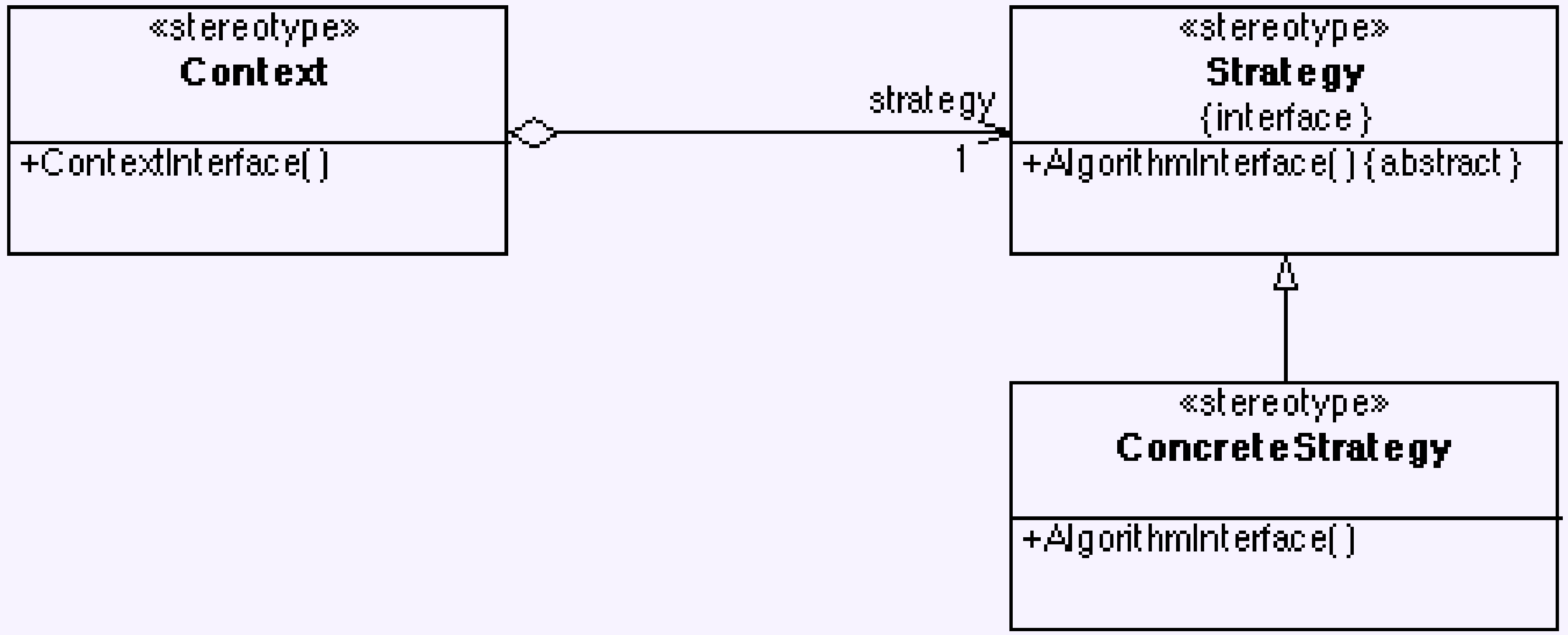
Layout Managers

```
panel.setLayout(new BorderLayout(0,0));
```

```
abstract class Container { // JPanel is a Container
        private LayoutManager layoutMgr;

        public doLayout() {
                LayoutManager m = this.layoutMgr;
                if (m!=null)
                        m.layoutContainer(this);
        }
        public Component[] getComponents() { … }
}
```

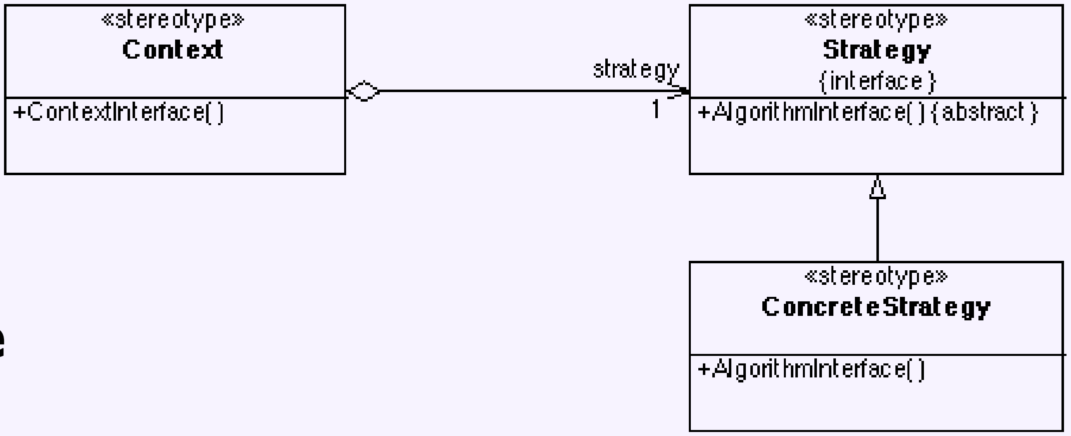
```
interface LayoutManager {
        void layoutContainer(Container c);
        Dimension getMinimumLayoutSize(Container c);
        Dimension getPreferredLayoutSize(Container c);
}
```

Behavioral: Strategy



Behavioral: Strategy

- Applicability
  - Many classes differ in only their behavior
  - Client needs different variants of an algorithm
- Consequences
  - Code is more **extensible** with new strategies
    - Compare to conditionals
  - Separates algorithm from context
    - each can vary independently
    - **design for change and reuse**; **reduce coupling**
  - Adds objects and dynamism
    - code harder to understand
  - Common strategy interface
    - may not be needed for all Strategy implementations – may be extra overhead



Tradeoffs

```
void sort(int[] list, String order) {
   …
  boolean mustswap;
  if (order.equals("up")) {
    mustswap = list[i] < list[j];
  } else if (order.equals("down")) {
    mustswap = list[i] > list[j];
  }
  …
}
```

```
void sort(int[] list, Comparator cmp) {
   …
  boolean mustswap;
  mustswap = cmp.compare(list[i], list[j]);
  …
}
interface Comparator {
  boolean compare(int i, int j);
}
class UpComparator implements Comparator {
  boolean compare(int I, int j) { return i<j; }}

class DownComparator implements Comparator {
  boolean compare(int I, int j) { return i>j; }}
```

Design Goals

- Design to explicit interfaces
  - Strategy: the algorithm interface
- Design for change and information hiding
  - Find what varies and encapsulate it
  - Allows adding alternative variations later
- Design for reuse
  - Strategy class may be reused in different contexts
  - Context class may be reused even if existing strategies don’t fit
- Low coupling
  - Decouple context class from strategy implementation internals
- Side note: how do you implement the Strategy pattern in functional languages?

Template Method vs Strategy vs Observer

- Template method vs strategy pattern
  - both support variations in larger common context
  - Template method uses inheritance + abstract method
  - Strategy uses interface and polymorphism (object composition)
  - strategy objects reusable across multiple classes; multiple strategy objects per class possible
  - Why is Layout in Swing using the Strategy pattern?
- Strategy vs observer pattern
  - both use a callback mechanism
  - Observer pattern supports multiple observers (0..n)
  - Update method in observer triggers update; rarely returns result
  - Strategy pattern supports exactly one strategy or an optional one if null is acceptable (0..1)
  - Strategy method represents a computation; may return a result

The Strategy Pattern to Paint Borders

- contentPane.setBorder(new EmptyBorder(5, 5, 5, 5));
  - Border interface has "paintBorder", "getBorderInsets" and "isBorderOpague" methods

```
//alternative design
class JPanel {
    protected void paintBorder(Graphics g) {
        switch(getBorderType()) {
            case LINE_BORDER: paintLineBorder(g); break;
            case ETCHED_BORDER: paintEtchedBorder(g); break;
            case TITLED_BORDER: paintTitledBorder(g); break;
            ...
        }
    }
}
```

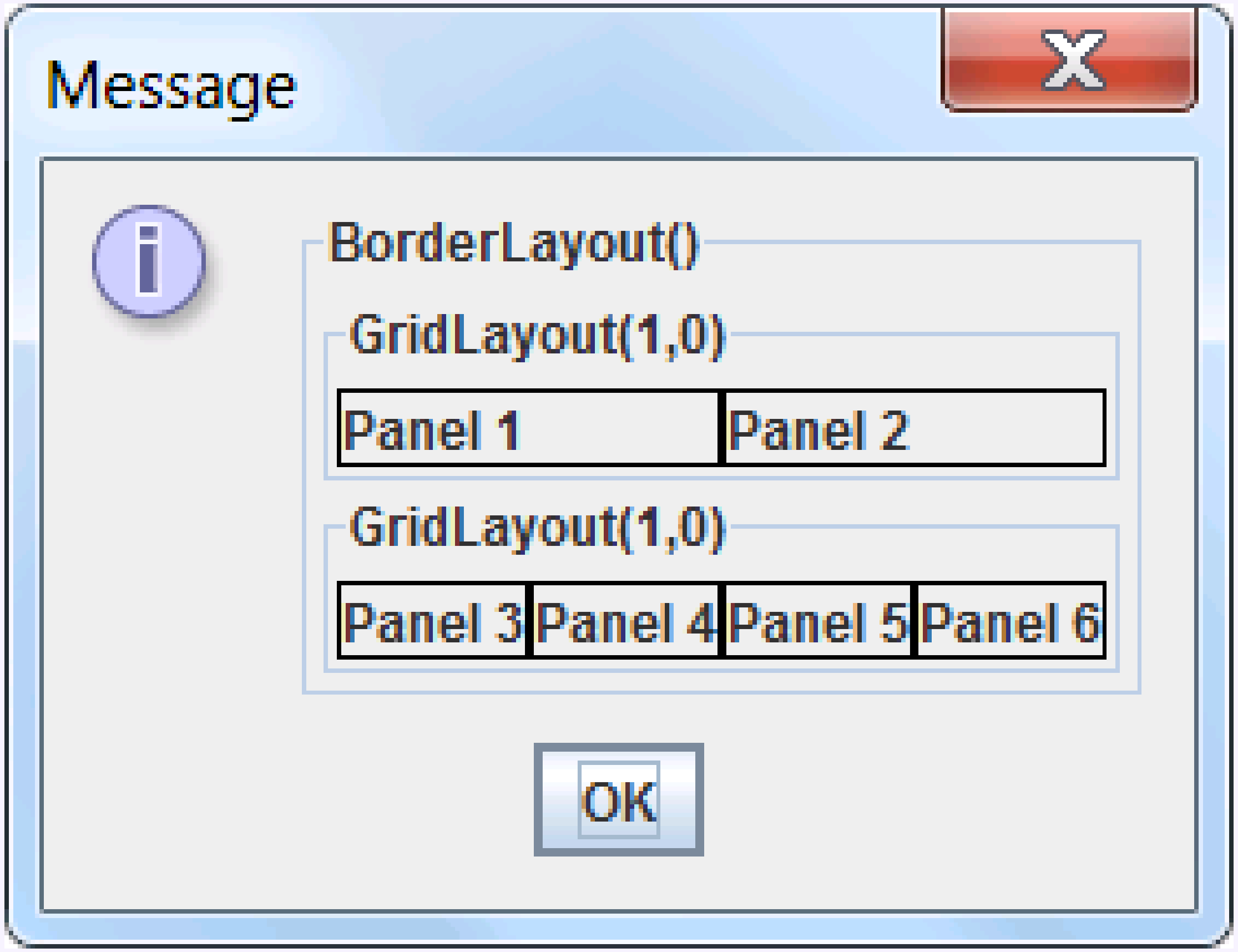
The Strategy Pattern to Paint Borders

- contentPane.setBorder(new EmptyBorder(5, 5, 5, 5));
  - Border interface has "paintBorder", "getBorderInsets" and "isBorderOpague" methods

```
//alternative design
class JPanel {
    protected void paintBorder(Graphics g) {
        switch(getBorderType()) {
            case LINE_BORDER: paintLineBorder(g); break;
            case ETCHED_BORDER: paintEtchedBorder(g); break;
            case TITLED_BORDER: paintTitledBorder(g); break;

    }
}
```

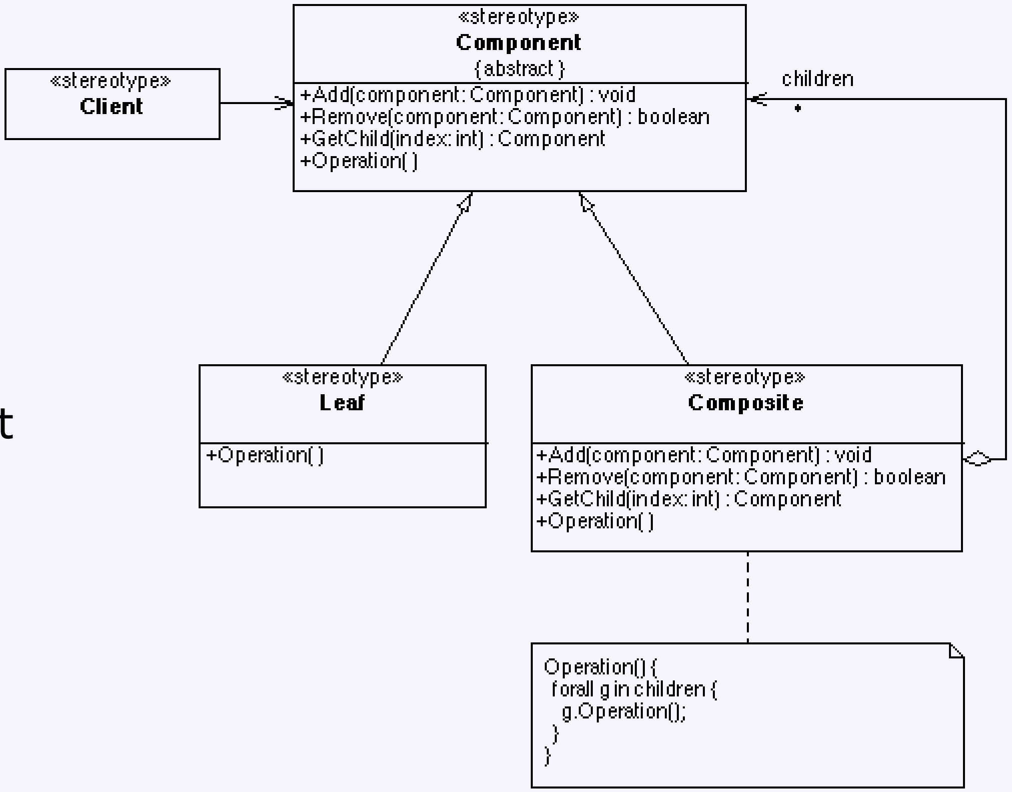
```
//actual JComponent implementation
protected void paintBorder(Graphics g) {
        Border border = getBorder();
        if (border != null)
                border.paintBorder(this, g, 0, 0, getWidth(), getHeight());
}
```

Nesting Containers



Reminder: Composite Design Pattern

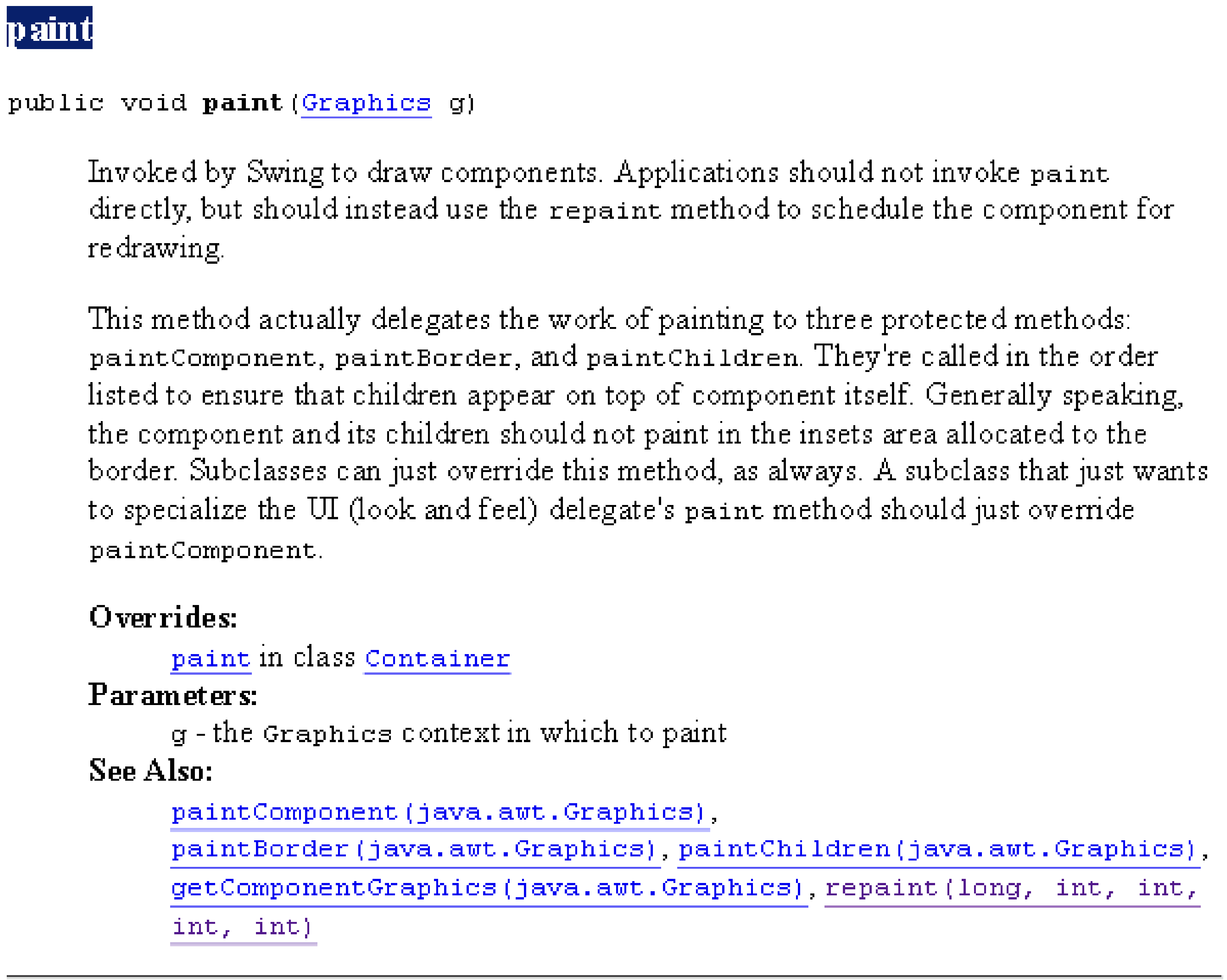
- Applicability
  - You want to represent part-whole hierarchies of objects
  - You want to be able to ignore the difference between compositions of objects and individual objects
- Consequences
  - Makes the client simple, since it can treat objects and composites uniformly
  - Makes it easy to add new kinds of components
  - Can make the design overly general
    - Operations may not make sense on every class
    - Composites may contain only certain components


«stereotype»
Client
«stereotype»
Component
{abstract}
+Add(component: Component) : void
+Remove(component: Component) : boolean
+GetChild(index: int) : Component
+Operation( )
children
*
«stereotype»
Leaf
+Operation( )
«stereotype»
Composite
+Add(component: Component) : void
+Remove(component: Component) : boolean
+GetChild(index: int) : Component
+Operation( )

```
Operation() {
 forall g in children {
   g.Operation();
 }
}
```

Drawing Widgets

JComponent



paint

```
public void paint(Graphics g)
```

Invoked by Swing to draw components. Applications should not invoke `paint` directly, but should instead use the `repaint` method to schedule the component for redrawing.

This method actually delegates the work of painting to three protected methods: `paintComponent`, `paintBorder`, and `paintChildren`. They're called in the order listed to ensure that children appear on top of component itself. Generally speaking, the component and its children should not paint in the insets area allocated to the border. Subclasses can just override this method, as always. A subclass that just wants to specialize the UI (look and feel) delegate's `paint` method should just override `paintComponent`.

Overrides:

`paint` in class `Container`

Parameters:

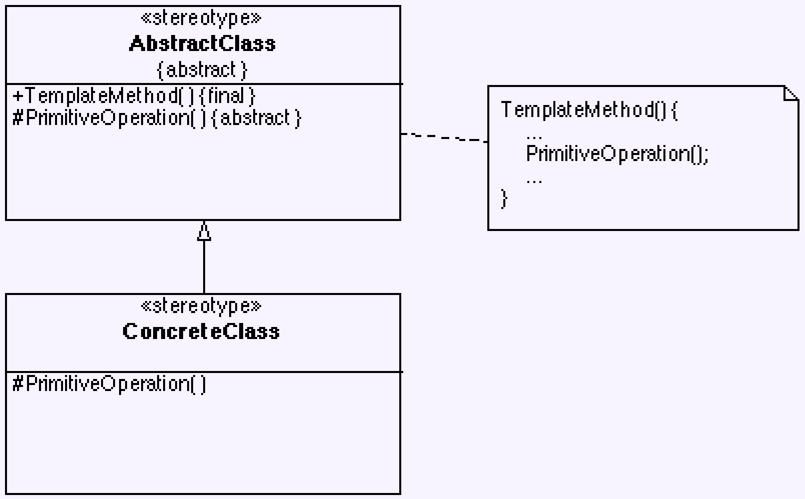
`g` - the `Graphics` context in which to paint

See Also:

`paintComponent(java.awt.Graphics)`, `paintBorder(java.awt.Graphics)`, `paintChildren(java.awt.Graphics)`, `getComponentGraphics(java.awt.Graphics)`, `repaint(long, int, int, int, int)`

Reminder: Template Method

- Applicability
  - When an algorithm consists of varying and invariant parts that must be customized
  - When common behavior in subclasses should be factored and localized to avoid code duplication
  - To control subclass extensions to specific operations
- Consequences
  - Code reuse
  - Inverted "Hollywood" control: don't call us, we'll call you
  - Ensures the invariant parts of the algorithm are not changed by subclasses



GUI design issues

- Interfaces vs. inheritance
  - Inherit from JPanel with custom drawing functionality
  - Implement the ActionListener interface, register with button
  - Why this difference?

- Models and views

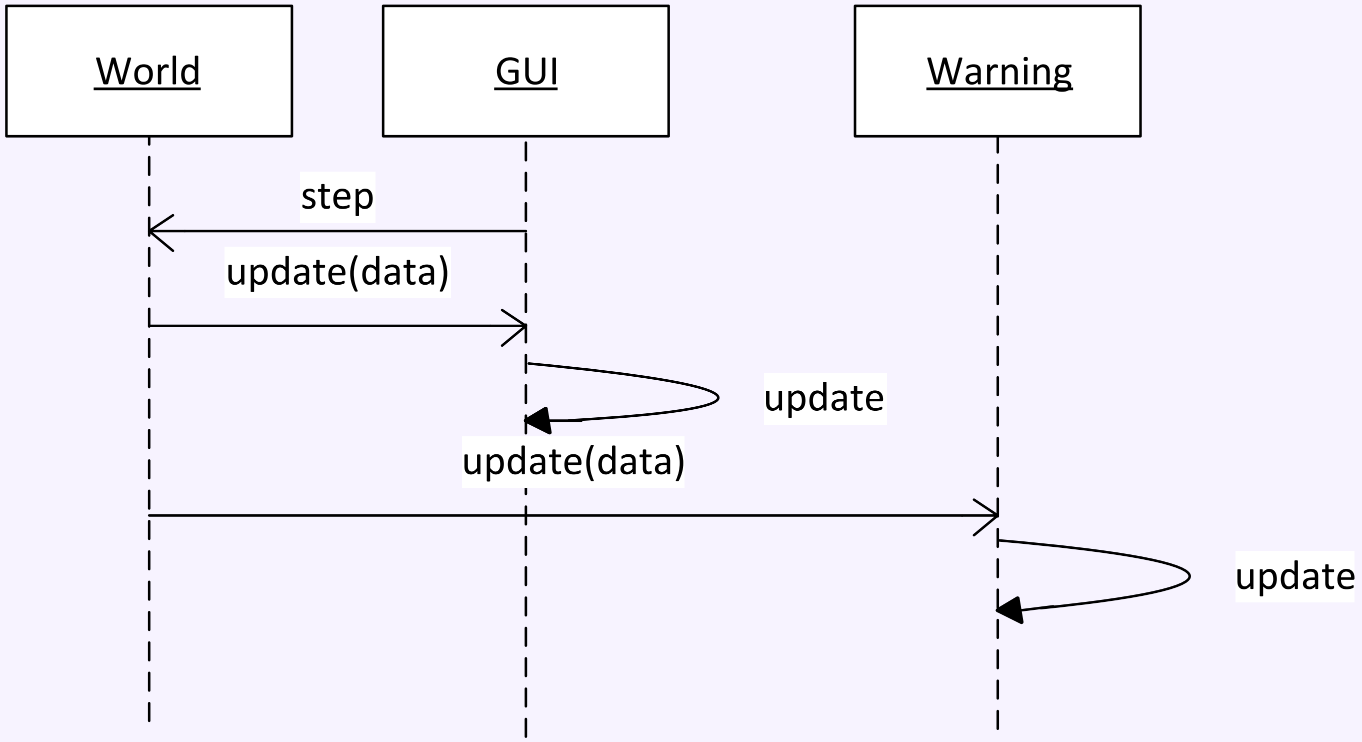
GUI design: Interfaces vs. inheritance

- Inherit from JPanel with custom drawing functionality
  - Subclass “is a” special kind of Panel
  - The subclass interacts closely with the JPanel – e.g. the subclass calls back with super
  - Accesses protected functionality otherwise not exposed
  - The way you draw the subclass doesn’t change as the program executes
- Implement the ActionListener interface, register with button
  - The action to perform isn’t really a special kind of button; it’s just a way of reacting to the button. So it makes sense to be a separate object.
  - The ActionListener is decoupled from the button. Once the listener is invoked, it doesn’t call anything on the Button anymore.
  - We may want to change the action performed on a button press—so once again it makes sense for it to be a separate object
- See also Command pattern later

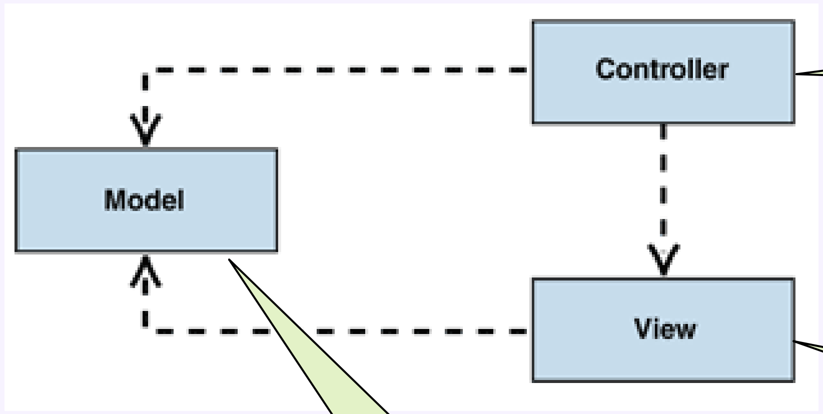
Separating Core and GUI

Core vs. GUI

- Core Implementation: Application logic
  - computing a result
  - updating some data
- GUI
  - Graphical representation of applications data
  - User interactions; starting point for actions
- Design Guideline: Separate core from GUI
  - Able to provide alternative GUIs
  - Able to test core separately
  - Keep GUI slim (no additional tests needed?)
  - Multithreading: keep GUI reactive also during long computations
  - -> **Design for change, design for reuse, design for division of labor; low coupling, high cohesion**


World
GUI
Warning
step
update(data)
update
update(data)
update

Metapattern: Model-View-Controller (MVC)



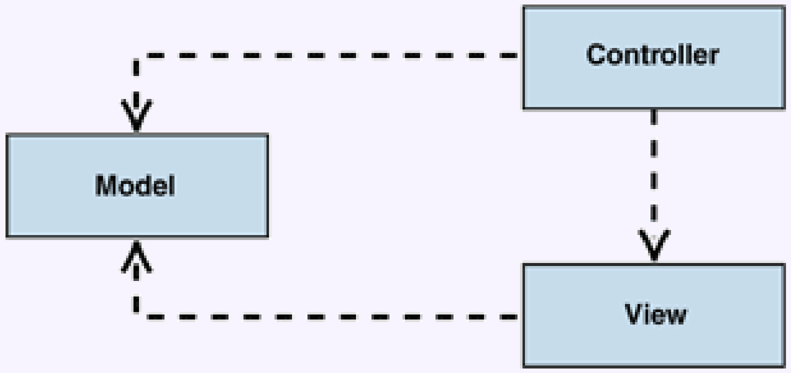
Manage inputs from user: mouse, keyboard, menu, etc.

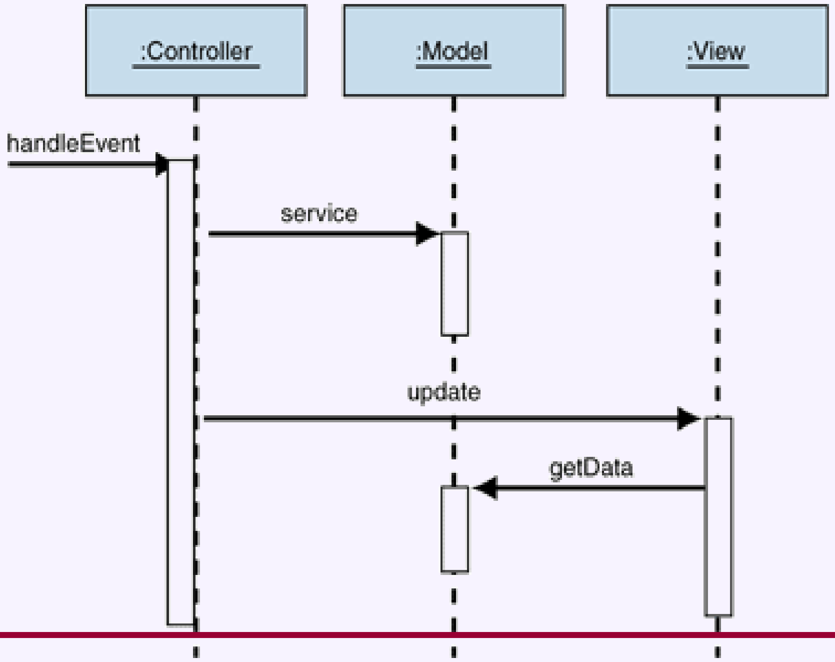
Manage display of information on the screen

Manage data related to the application domain

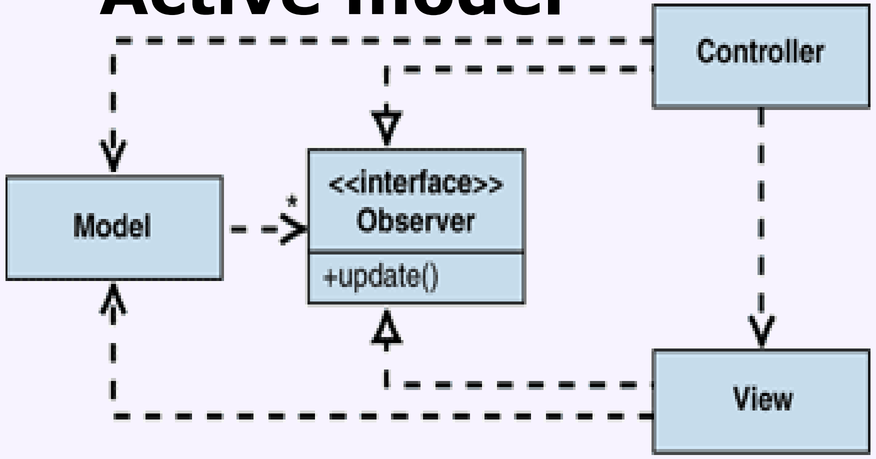
Model-View-Controller (MVC)

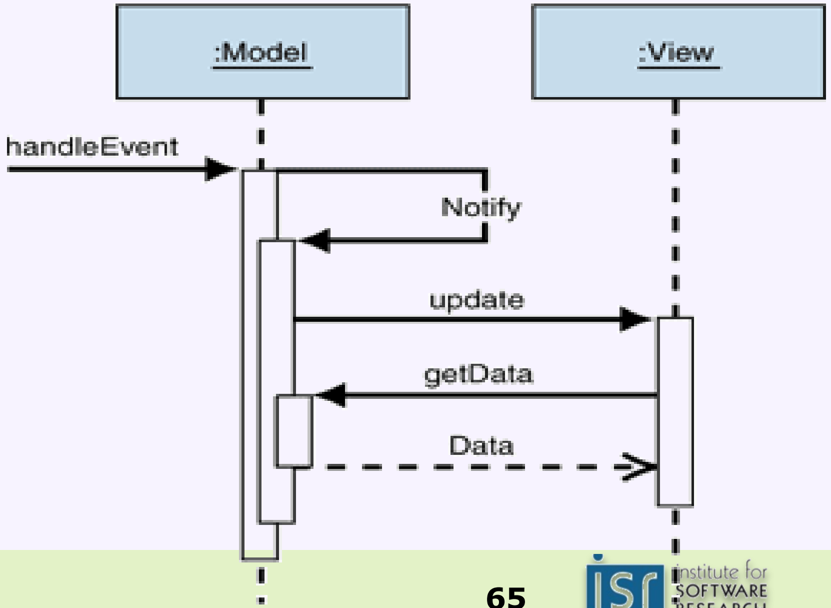
Passive model





Active model

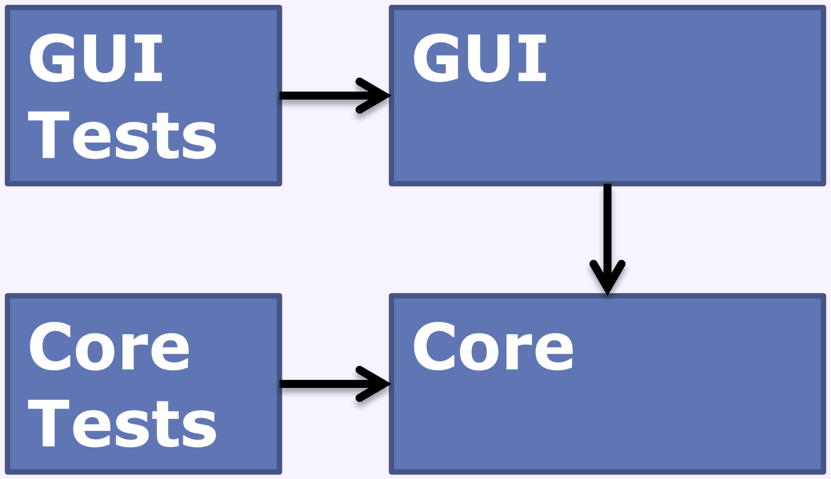




http://msdn.microsoft.com/en-us/library/ff649643.aspx

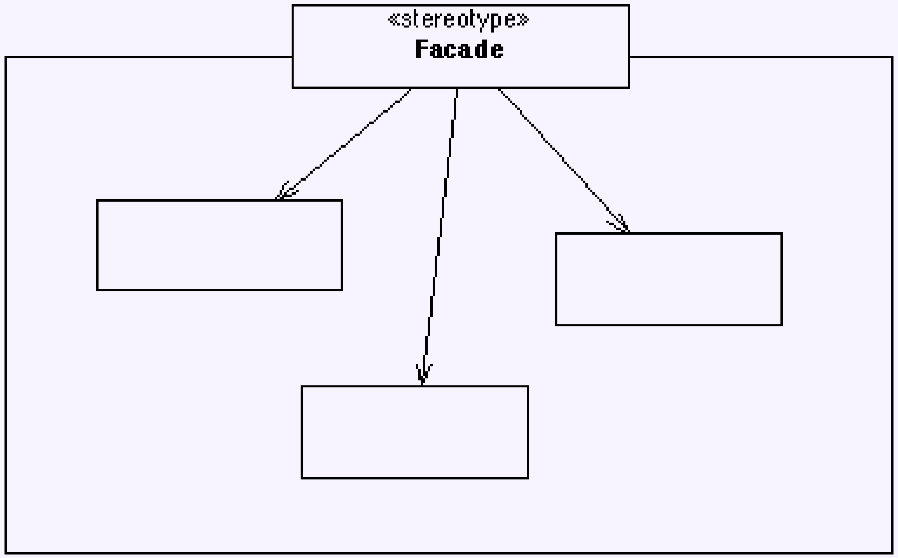
Separating Application Core and GUI

- Reduce coupling
- Create core of the application working and testable without a GUI
  - Use Observer pattern to communicate information from Core (Model) to GUI (View)
  - Use Controller (Façade) to perform operations on core
  - May run in separate threads (worker thread vs GUI thread) to avoid blocking, see SwingWorker



The *Façade* Design Pattern

- See GRASP Controller
- Applicability
  - You want to provide a simple interface to a complex subsystem
  - You want to decouple clients from the implementation of a subsystem
  - You want to layer your subsystems



- Consequences
  - It shields clients from the complexity of the subsystem, making it easier to use
  - **Decouples** the subsystem and its clients, making each easier to change
  - Clients that need to can still access subsystem classes
  - -> **Explicit interfaces, low coupling, information hiding, design for reuse, design for understandability, …**

Filling Lists and Tables

JList and JTree

- Lists and trees highly flexible (reusable)
- Can change rendering of cells
- Can change source of data to display

```
//simple use
String [] items = { “a”, “b”, “c” };
JList list = new JList(items);
```

The ListModel

- Allows list widget (view) to react to changes in the model

```
//with a ListModel
ListModel model = new DefaultListModel();
model.addElement("a");
JList list = new JList(model);
```

```
interface ListModel<T> {
        int getSize();
        T getElementAt(int index);
        void addListDataListener(ListDataListener l);
        void removeListDataListener(ListDataListener l);
}
```

The ListModel

- Allows list widget (view) to react to changes in the model

```
//with a ListModel
ListModel model = new DefaultListModel();
model.addElement(“a”);
JList list = new JList(model);
```

```
interface ListModel<T> {
        int getSize();
}
```

```
interface ListDataListener extends EventListener {
        void intervalAdded(…);
        void intervalRemoved(…);
        void contentsChanged(…);
}
```

Scenario

- Assume we want to show all items of the virtual world in a list and update the items

```
//design 1
class World implements ListModel<String> {
        List<Item> items …

        int getSize() { return items.size(); }
        String getElementAt(int index) {
                items.get(index).getName();
        }
        void addListDataListener(ListDataListener l) {…}
        protected void fireListUpdated() {…}
}
```

Scenario

- Assume we want to show all items of the virtual world in a list and update the items

```
//design 2
class World {
        DefaultListModel<Item> items …

        public getListModel() { return items; }
        public Iterable<Item> getItems() {
                return items.elements();

}
```

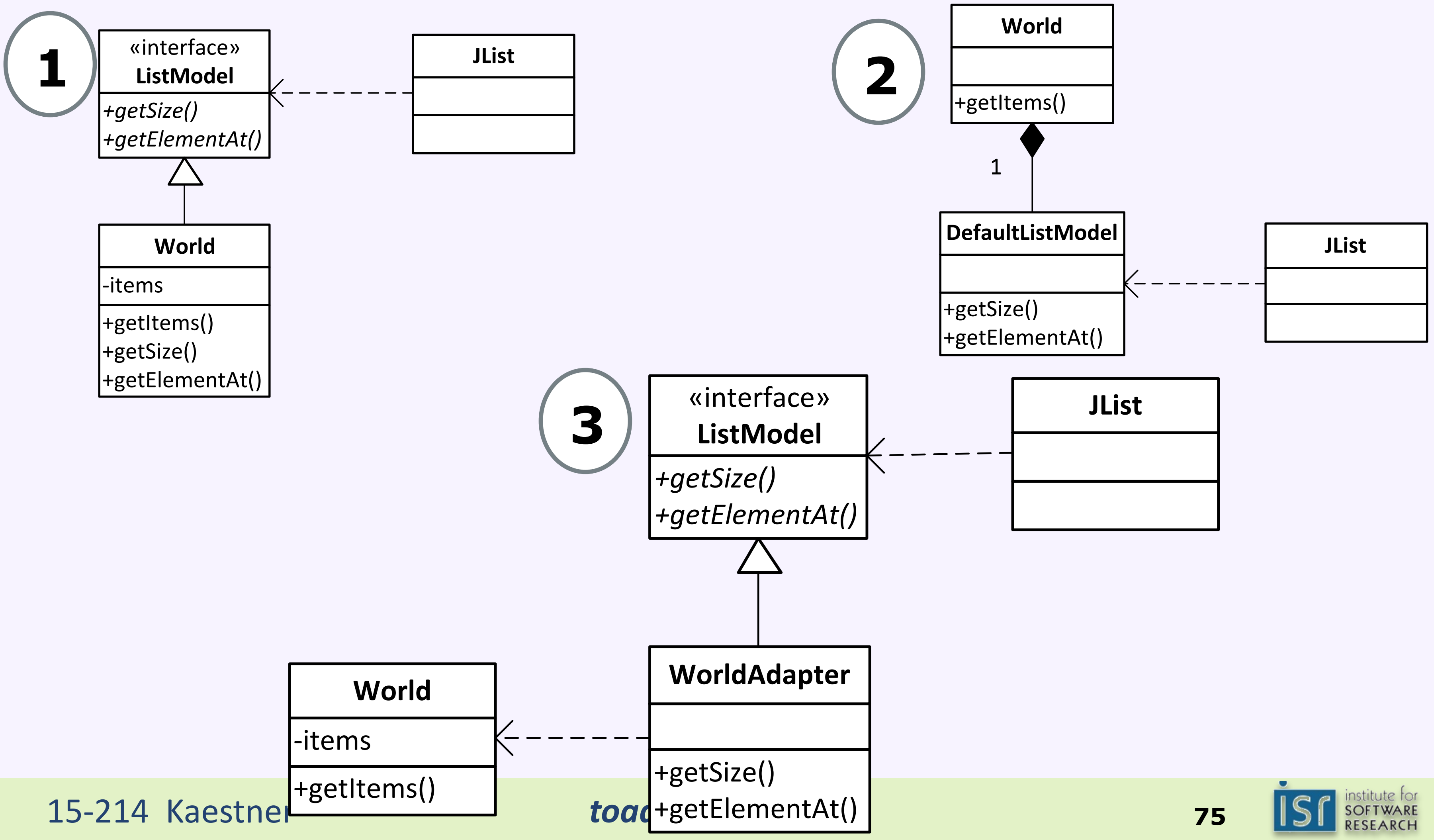
Scenario

- Assume we want to show all items of the virtual world in a list and update the items

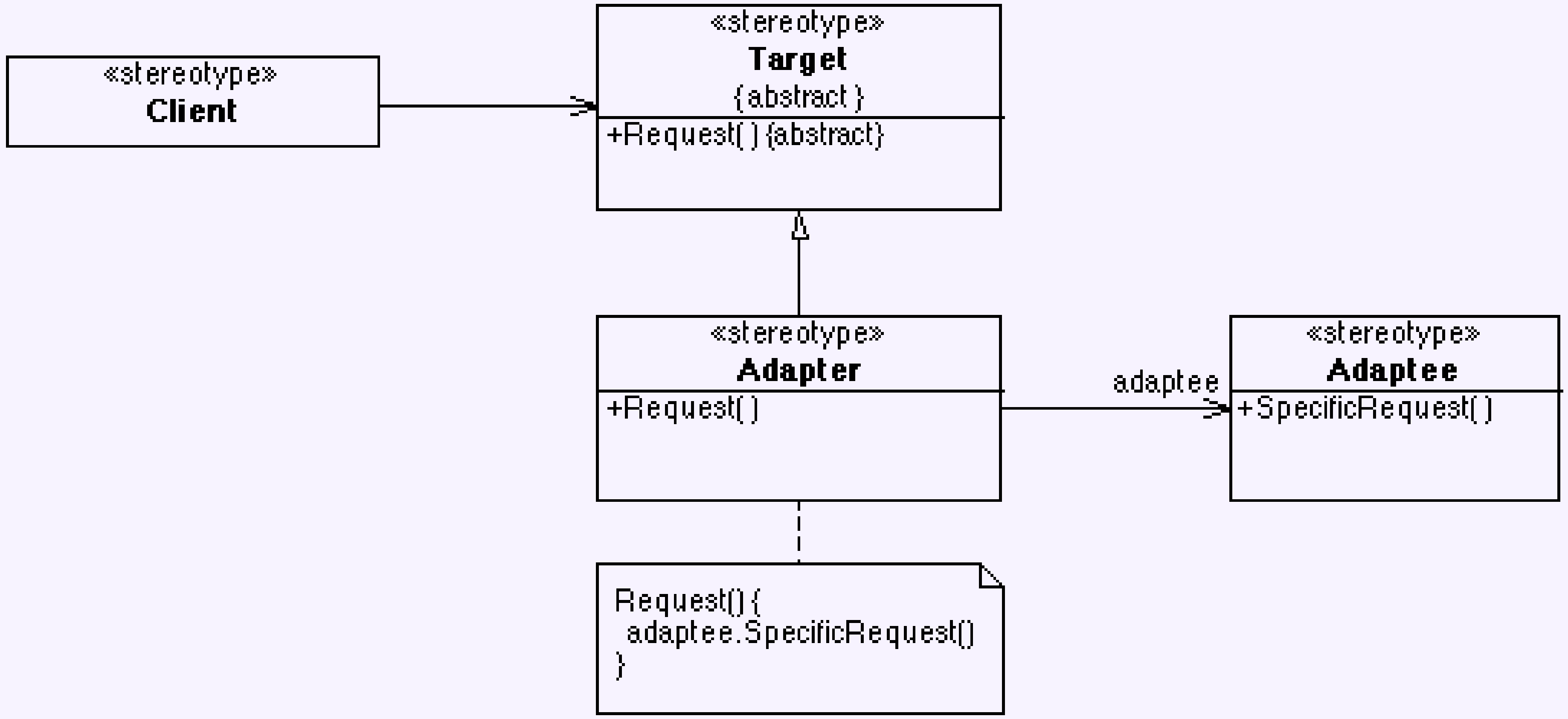
```
//design 3
class WorldAdapter implements ListModel<String> {
	private final World world;
	public WorldAdapter(World w) {world = w;}

	int getSize() { return count(world.getItems()); }
	String getElementAt(int index) {
		find(world.getItems(), index);
	}
	void addListDataListener(ListDataListener l) {…}
	…
}
```

Scenario

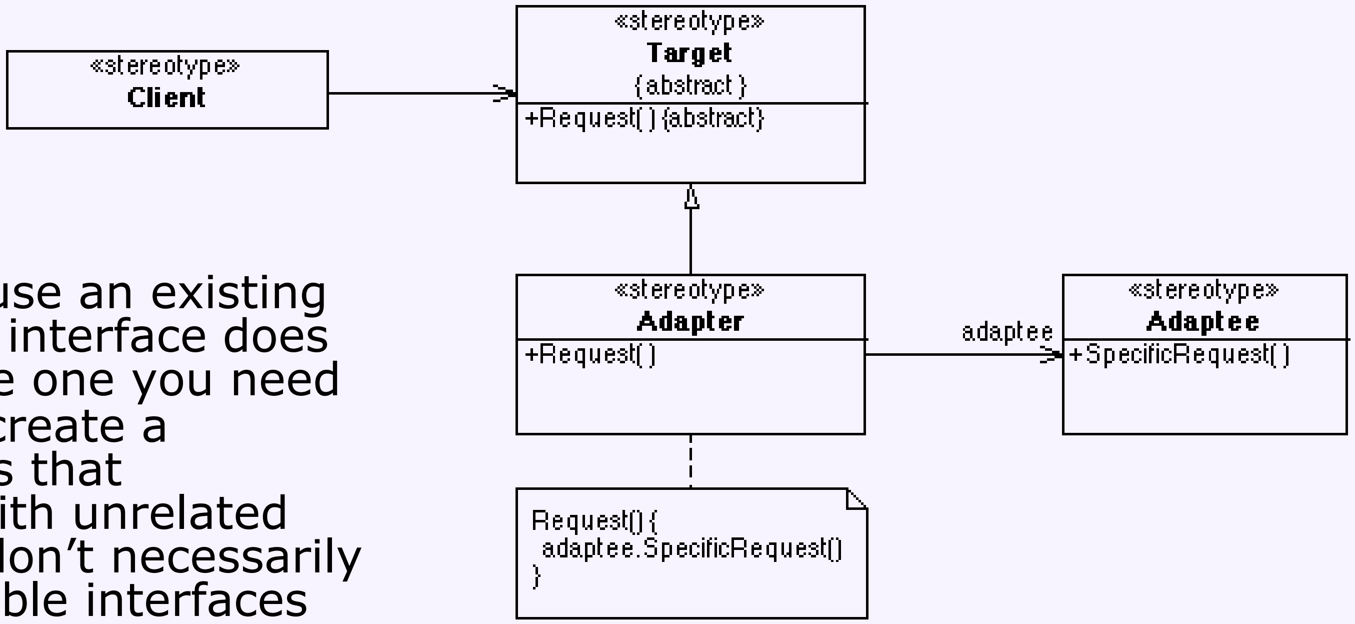
- Assume we want to show all items of the virtual world in a list and update the items



The *Adapter* Design Pattern



The *Adapter* Design Pattern



- Applicability
  - You want to use an existing class, and its interface does not match the one you need
  - You want to create a reusable class that cooperates with unrelated classes that don't necessarily have compatible interfaces
  - You need to use several subclasses, but it's impractical to adapt their interface by subclassing each one

•Consequences
- Exposes the functionality of an object in another form
- Unifies the interfaces of multiple incompatible adaptee objects
- Lets a single adapter work with multiple adaptees in a hierarchy
- -> **Low coupling, high cohesion**

Other Scenarios for Adapters

- You have an application that processes data with an Iterator. Methods are:
  - **boolean** hasNext();
  - Object next();

- You need to read that data from a database using JDBC. Methods are:
  - **boolean** next();
  - Object getObject(int column);

- You might have to get the information from other sources in the future.

Façade vs. Adapter

- Motivation
  - Façade: simplify the interface
  - Adapter: match an existing interface

- Adapter: interface is given
  - Not typically true in Façade

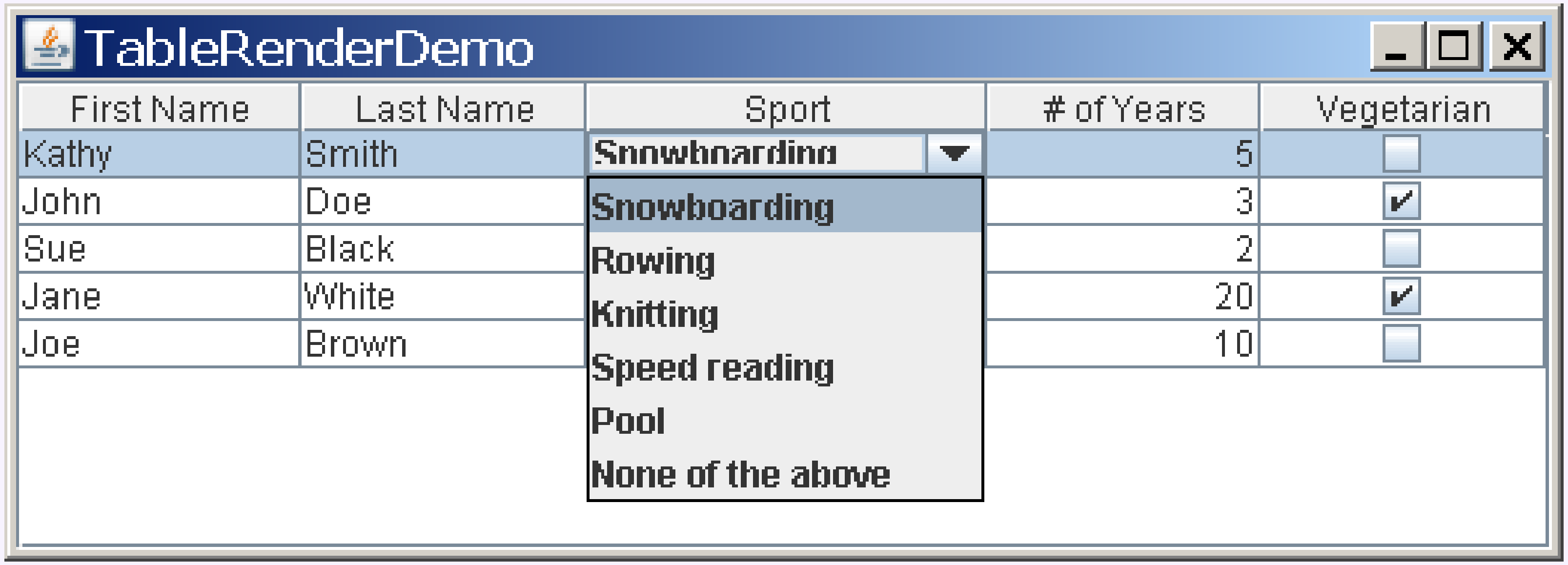
- Adapter: polymorphic
  - Dispatch dynamically to multiple implementations
  - Façade: typically choose the implementation statically

Design Goals

- Design to explicit interfaces
  - Façade – a new interface for a library
  - Adapter – design application to a common interface, adapt other libraries to that
- Favor composition over inheritance
  - Façade – library is composed within Façade
  - Adapter – adapter object interposed between client and implementation
- Design for change with information hiding
  - Both Façade and Adapter – shields variations in the implementation from the client
- Design for reuse
  - Façade provides a simple reusable interface to subsystem
  - Adapter allows to reuse objects without fitting interface
- …

Custom Renderer

- Renderer of list items and table cells exchangable
- Interface TableCellRenderer
- Strategy design pattern, again

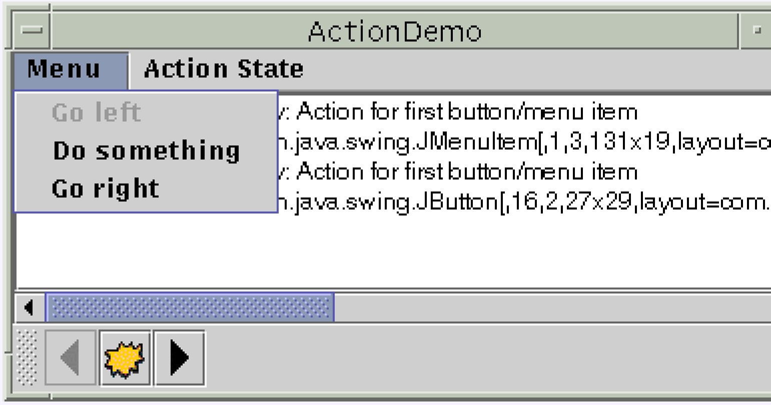


First Name	Last Name	Sport	# of Years	Vegetarian
Kathy	Smith	Snowboarding	5	☐
John	Doe		3	✓
Sue	Black		2	☐
Jane	White		20	✓
Joe	Brown		10	☐

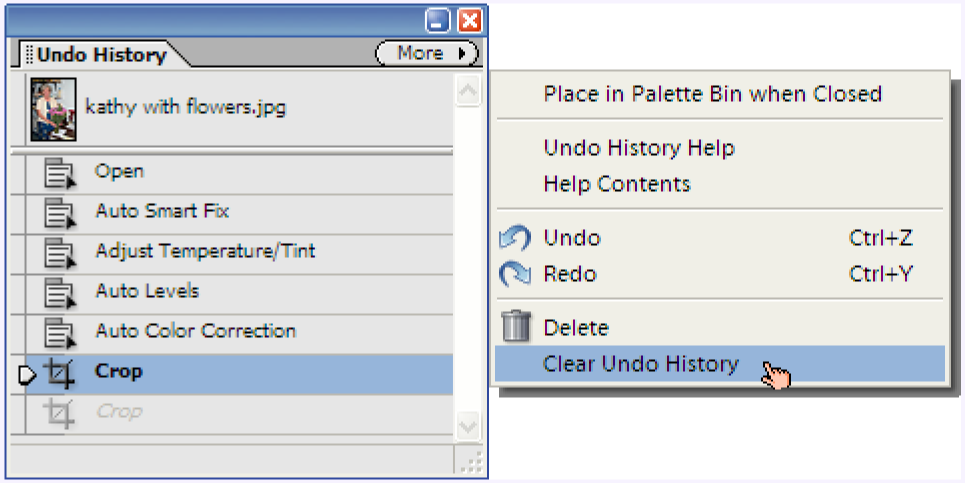
Undoable Actions

Actions in GUIs

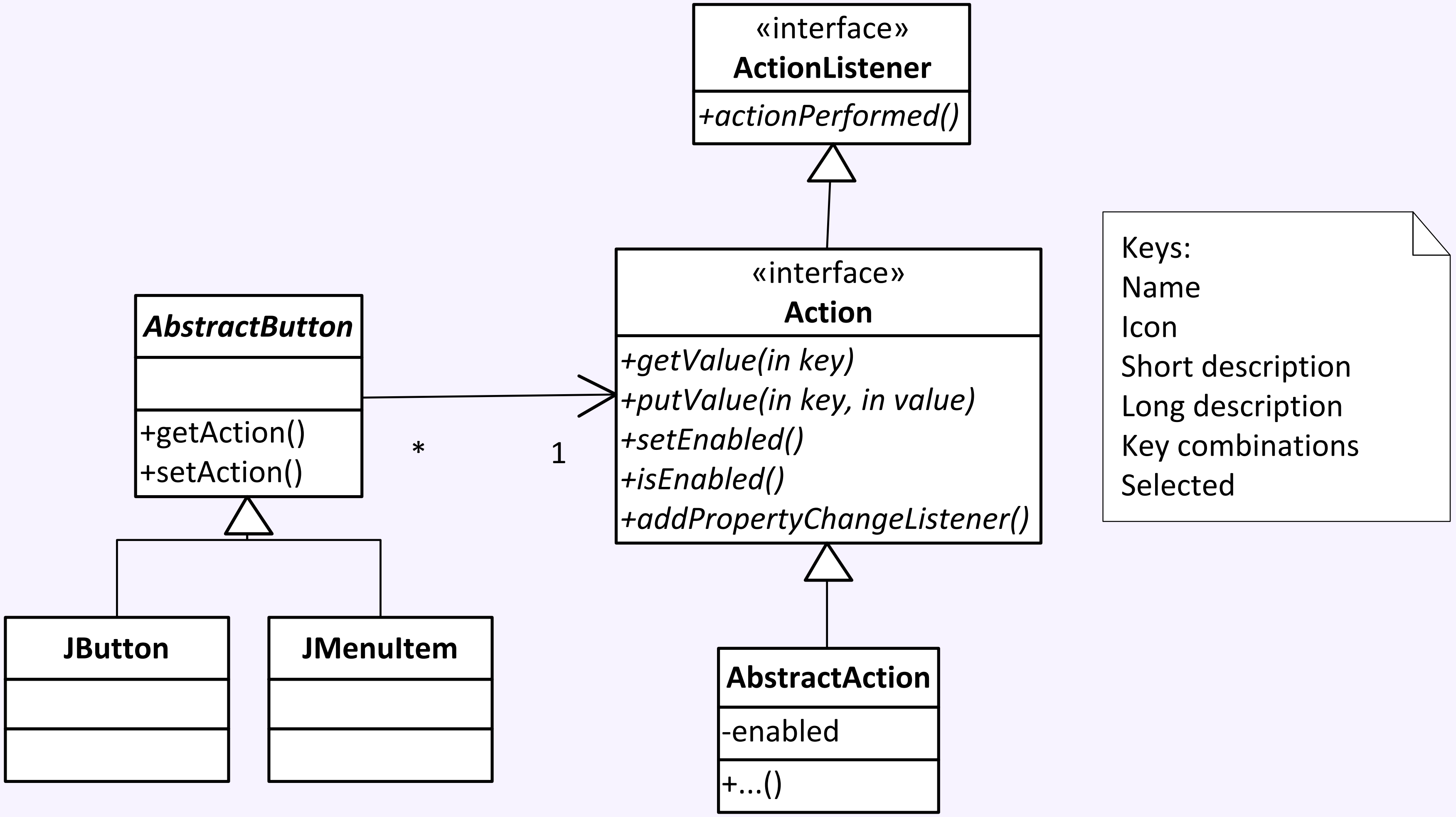
- We want to make actions accessible in multiple places
  - menu, context menu, keyboard shortcut, …
  - When disabling an action, all places should be disabled
- We may want to undo actions
- Separate action execution from presentation
- Delay, queue, or log actions
  - eg macro recording, progress bars, executing remotely, transactions, wizards



```
: Action for first button/menu item
.java.swing.JMenuItem[,1,3,131x19,layout=c
: Action for first button/menu item
.java.swing.JButton[,16,2,27x29,layout=com.
```



Actions in Swing

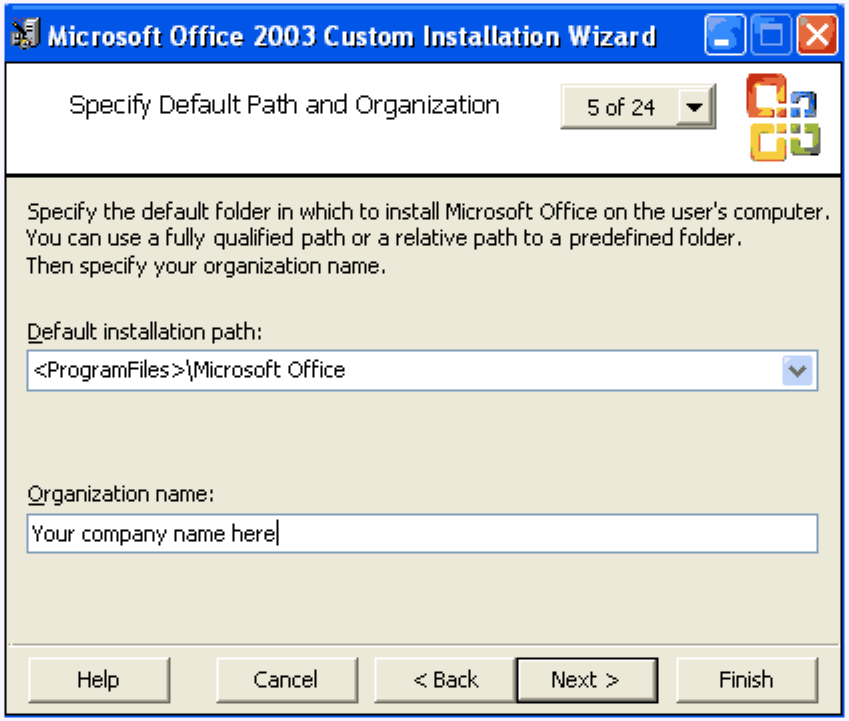


Action vs. ActionListener

- Action is self-describing (text, shortcut, icon, …)
  - Can be used in many places
  - e.g. log of executed commands, queue, undo list
- Action can have state (enabled, selected, …)
- Actions are synchronized in all cases where they are used
  - with observer pattern: PropertyChangeListener

Implementing a Wizard

- Every step produces some execution
- Execution is delayed until user clicks finish
- Collect objects representing executions in a list
- Execute all at the end
- -> Design for change, division of labor, and reuse; low coupling


Microsoft Office 2003 Custom Installation Wizard

Specify Default Path and Organization

5 of 24

Specify the default folder in which to install Microsoft Office on the user's computer. You can use a fully qualified path or a relative path to a predefined folder. Then specify your organization name.

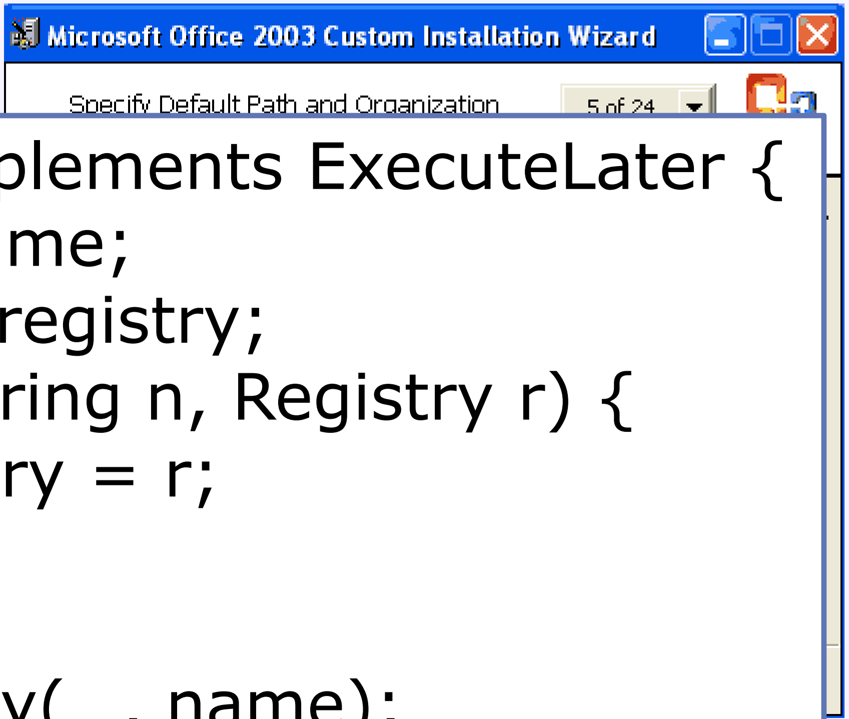
Default installation path: <ProgramFiles>\Microsoft Office

Organization name: Your company name here

```
interface ExecuteLater {
      void execute();
}
```

Implementing a Wizard

- Every step produces some execution

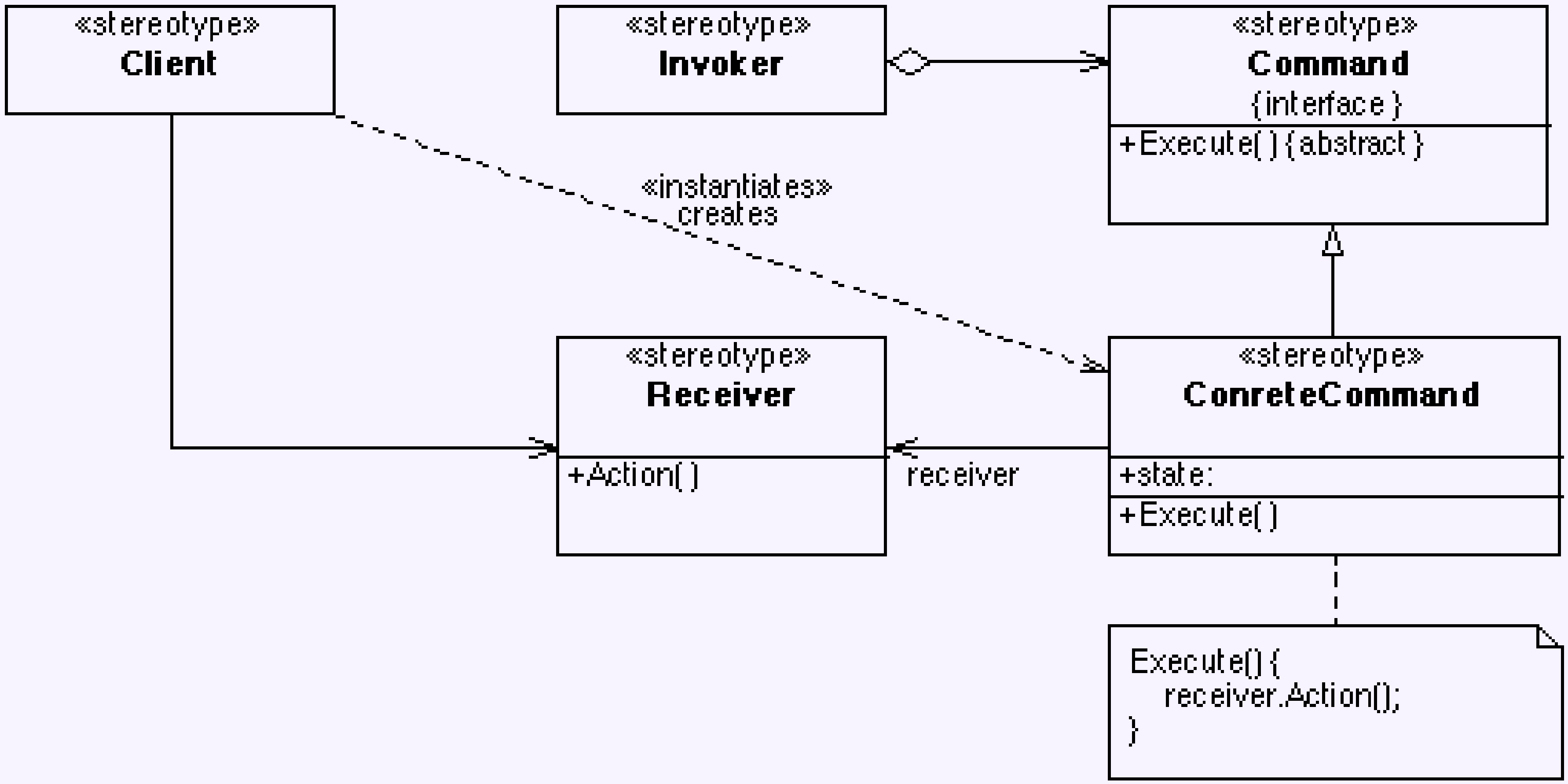

Microsoft Office 2003 Custom Installation Wizard
Specify Default Path and Organization
5 of 24

```
class SetCompanyName implements ExecuteLater {
        private final String name;
        private final Registry registry;
        SetCompanyName(String n, Registry r) {
                name=n; registry = r;
        }
        void execute() {
                registry.writeKey(…, name);
        }
}
```

reuse; low coupling

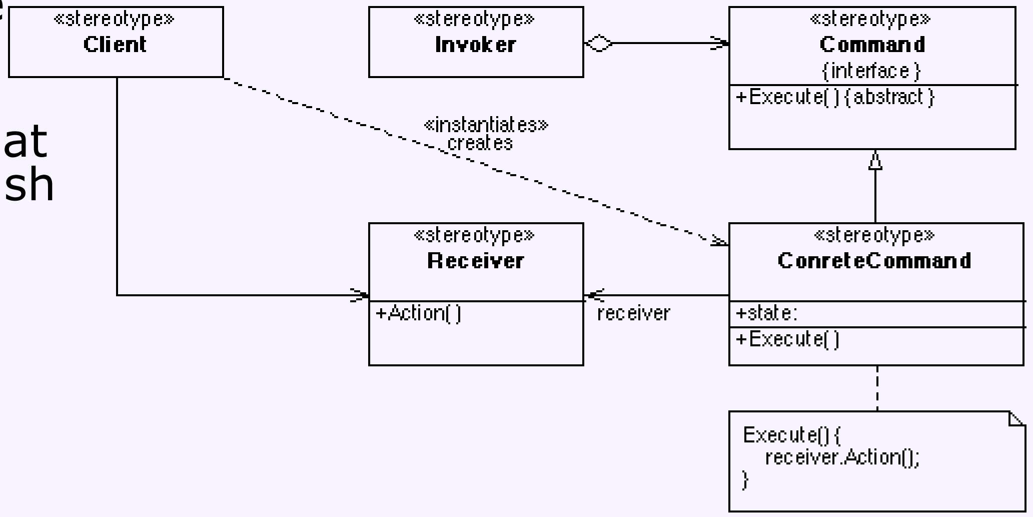
```
        void execute();
}
```

The *Command* Design Pattern



The *Command* Design Pattern

- Applicability
  - Parameterize objects by an action to perform
  - Specify, queue and execute requests at different times
  - Support undo
  - Support logging changes that can be reapplied after a crash
  - Structure a system around high-level operations built out of primitives
- Consequences
  - Decouples the object that invokes the operation from the one that performs it
  - Since commands are objects they can be explicitly manipulated
  - Can group commands into composite commands
  - Easy to add new commands without changing existing code



Common Commands in Java

- javax.swing.Action
  - see above

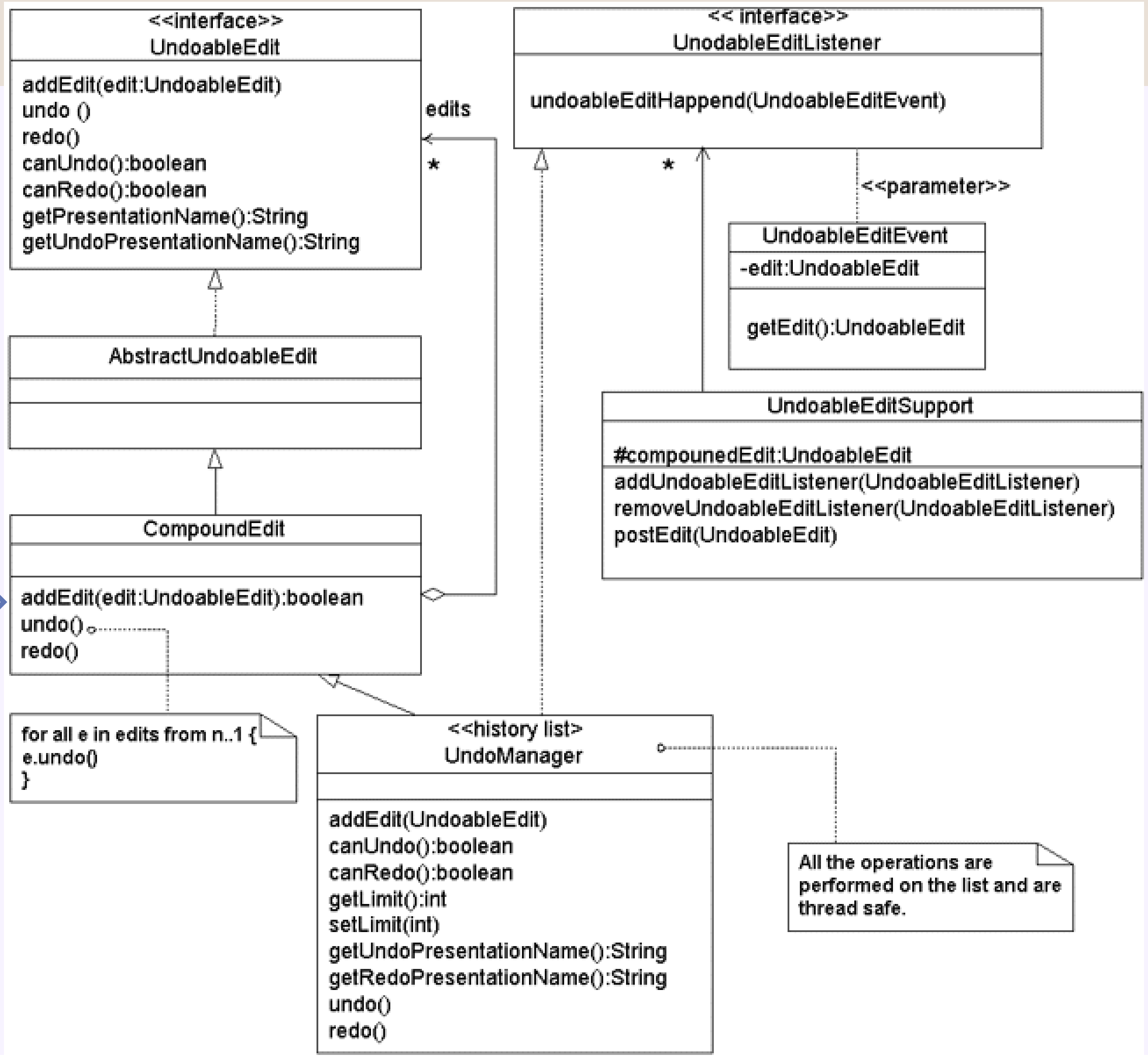
- java.lang.Runnable
  - Used as an explicit operation that can be passed to threads, workers, timers and other objects or delayed or remote execution
  - see FutureTask

Commands in the Virtual World

- Represent common actions
  - Reusing implementation
  - Validity checking of moves (e.g., MoveCommand can only be called on moveable items; rabbits may only move within moving range)
- Could be queued and checked separately
- Separate creation of command from its execution:
  - AI: Command getNextAction(ArenaWorld)
    vs
    Command: void execute(World)
  - Both can throw different kinds of exceptions

Undoable Actions

- Remember undoable changes: Store effect with information how to undo it in a list
  - Delete command with removed text and location
  - Paste command with location of added text
  - Swing: UndoableEdit interface
- Provide an undo and redo implementation for each undoable change
- Queue undoable changes in a history; provide user interface actions for undo and redo

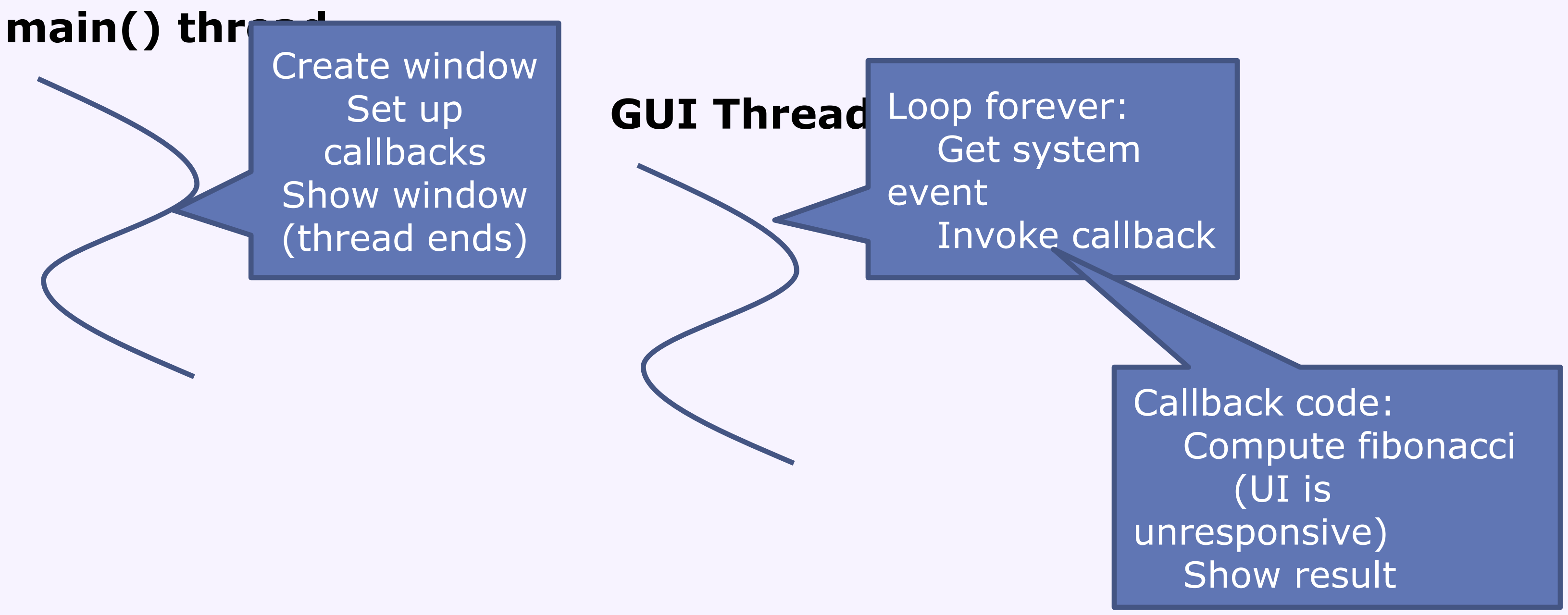


<<interface>>
UndoableEdit
addEdit(edit:UndoableEdit)
undo ()
redo()
canUndo():boolean
canRedo():boolean
getPresentationName():String
getUndoPresentationName():String
edits
*
<< interface>>
UnodableEditListener
undoableEditHappend(UndoableEditEvent)
*
<<parameter>>
UndoableEditEvent
-edit:UndoableEdit
getEdit():UndoableEdit
AbstractUndoableEdit
UndoableEditSupport
#compounedEdit:UndoableEdit
addUndoableEditListener(UndoableEditListener)
removeUndoableEditListener(UndoableEditListener)
postEdit(UndoableEdit)
CompoundEdit
addEdit(edit:UndoableEdit):boolean
undo()
redo()
for all e in edits from n..1 {
e.undo()
}
<<history list>
UndoManager
addEdit(UndoableEdit)
canUndo():boolean
canRedo():boolean
getLimit():int
setLimit(int)
getUndoPresentationName():String
getRedoPresentationName():String
undo()
redo()
All the operations are performed on the list and are thread safe.

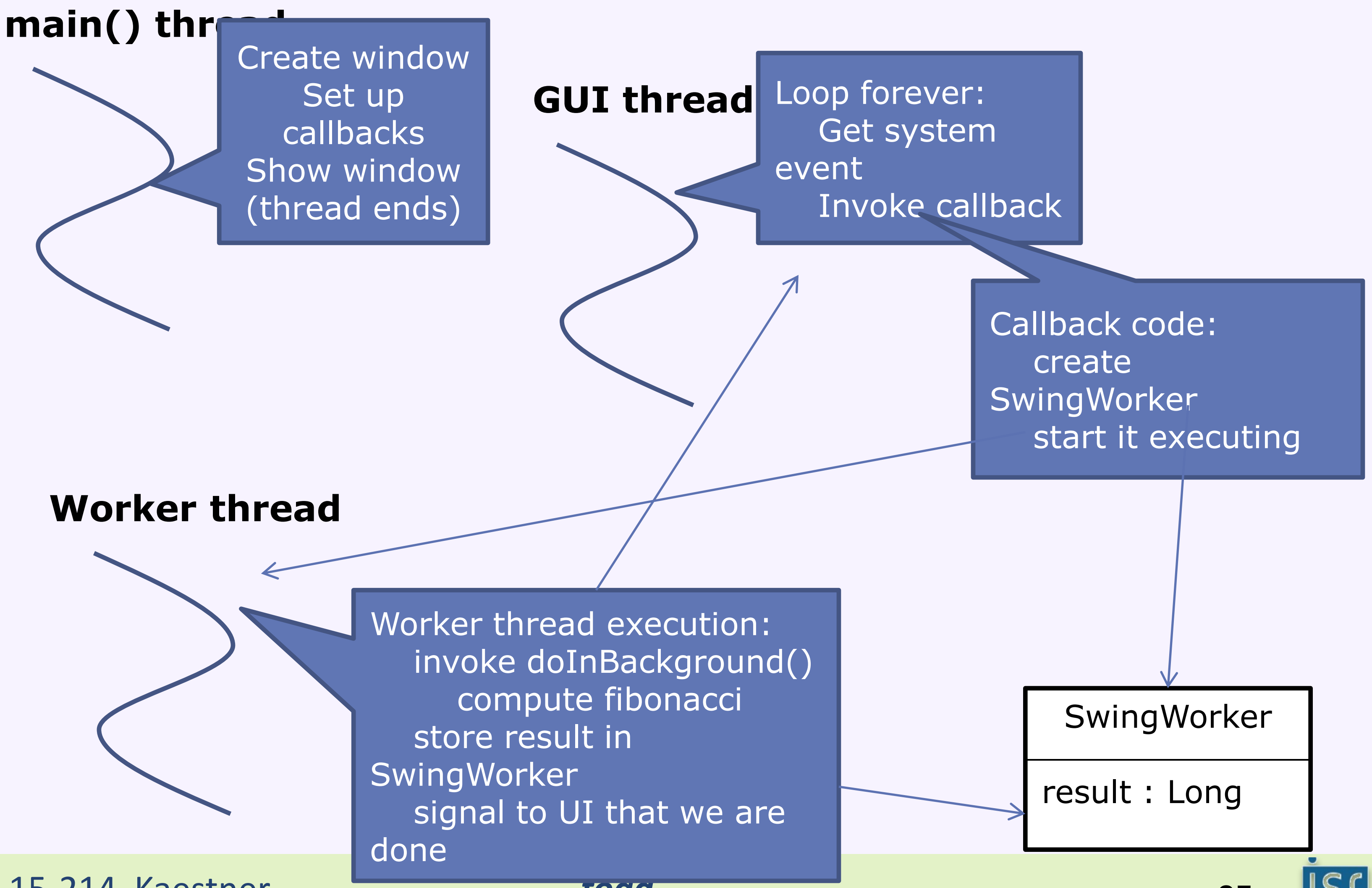
notice the composite pattern

Source: http://www.javaworld.com/article/2076698/core-java/add-an-undo-redo-function-to-your-java-apps-with-swing.html

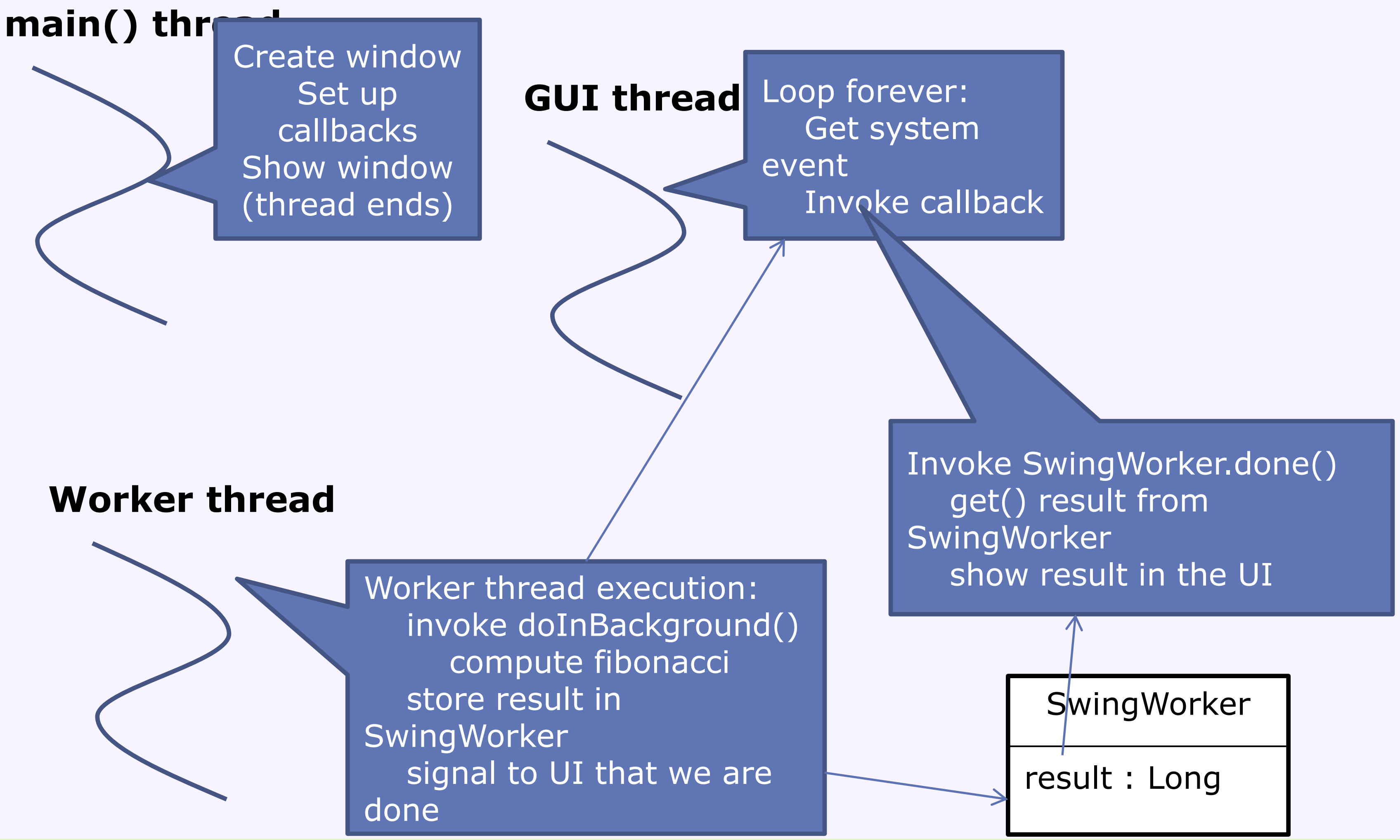
The GUI Threading Architecture


main() thr
Create window Set up callbacks Show window (thread ends)
GUI Thread
Loop forever: Get system event Invoke callback
Callback code: Compute fibonacci (UI is unresponsive) Show result

The GUI Threading Architecture



The GUI Threading Architecture



Summary

- GUIs are full of design pattern
  - Strategy Pattern
  - Template Method Pattern
  - Composite Pattern
  - Observer Pattern
  - Façade Pattern
  - Adapter Pattern
  - Command Pattern
  - Model-View-Controller Metapattern
- Swing for Java GUIs
- Separation of GUI and Core

Design Challenge

- In the Point of Sales terminal the total of a sale should be computed and coupons should be taken into account
- Coupons and other special actions may change over time: design for change
- Design 1-3 solutions that share common computations, but is extensible for new coupons or other promotions