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9. GUI Construction

Oscar Nierstrasz

GUI Construction

Sources

- David Flanagan, *Java in Nutshell: 5th edition*, O'Reilly.
- David Flanagan, Java Foundation Classes in a Nutshell, O'Reilly
- http://java.sun.com/docs/books/tutorial/uiswing

- ant.apache.org

Roadmap

- Model-View-Controller (MVC)
- Swing Components, Containers and Layout Managers
- Events and Listeners
- Observers and Observables
- Jar files, Ant and Javadoc
- Epilogue: distributing the game

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A Graphical TicTacToe?

Our existing TicTacToe implementation is very limited:

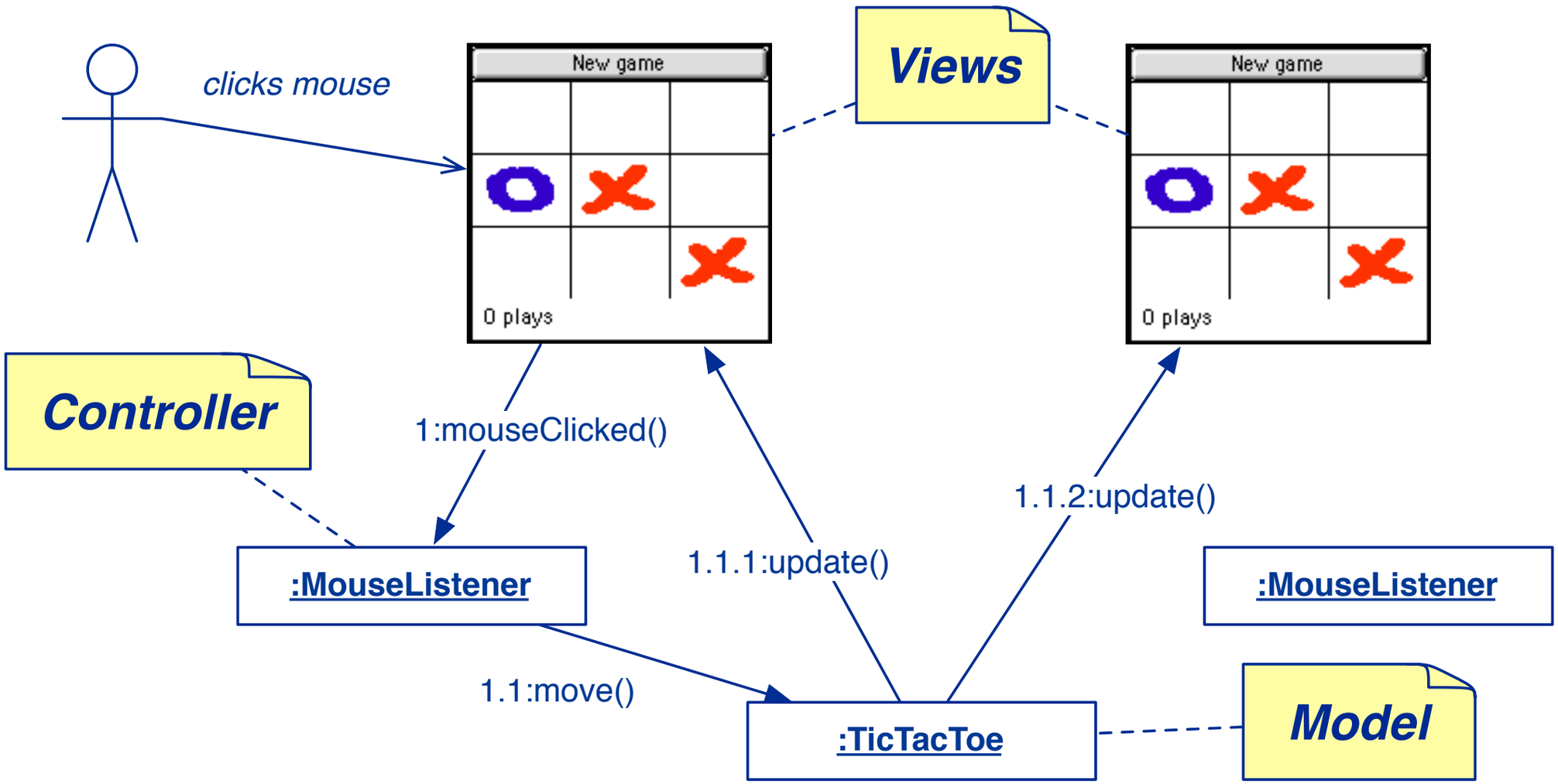
- single-user at a time
- textual input and display

We would like to migrate it towards an interactive game:

- running the game with *graphical display and mouse input*

Model-View-Controller

Version 6 of our game implements a *model of the game*, without a GUI. The `GameGUI` will implement a *graphical view* and a *controller for GUI events.*



The MVC paradigm separates an application from its GUI so that multiple views can be dynamically connected and updated.

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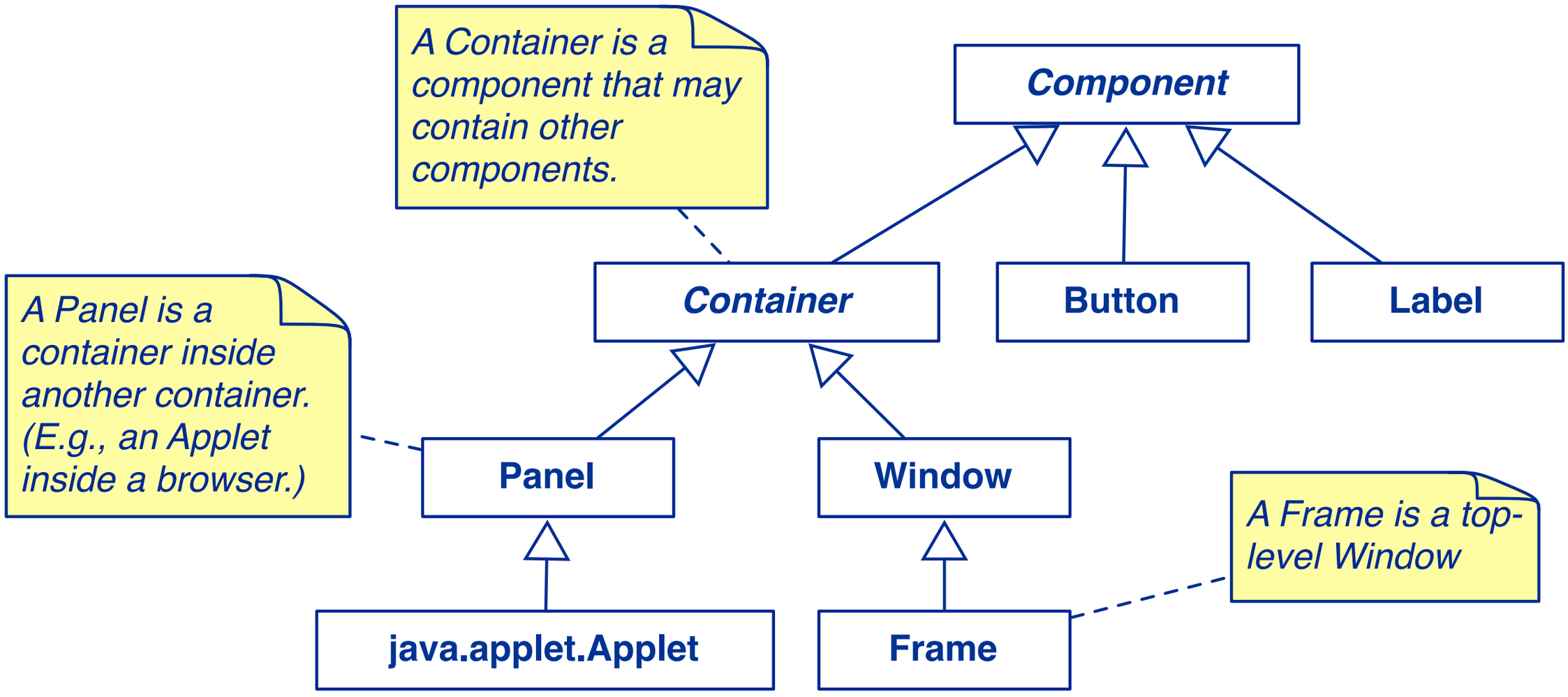
AWT Components and Containers

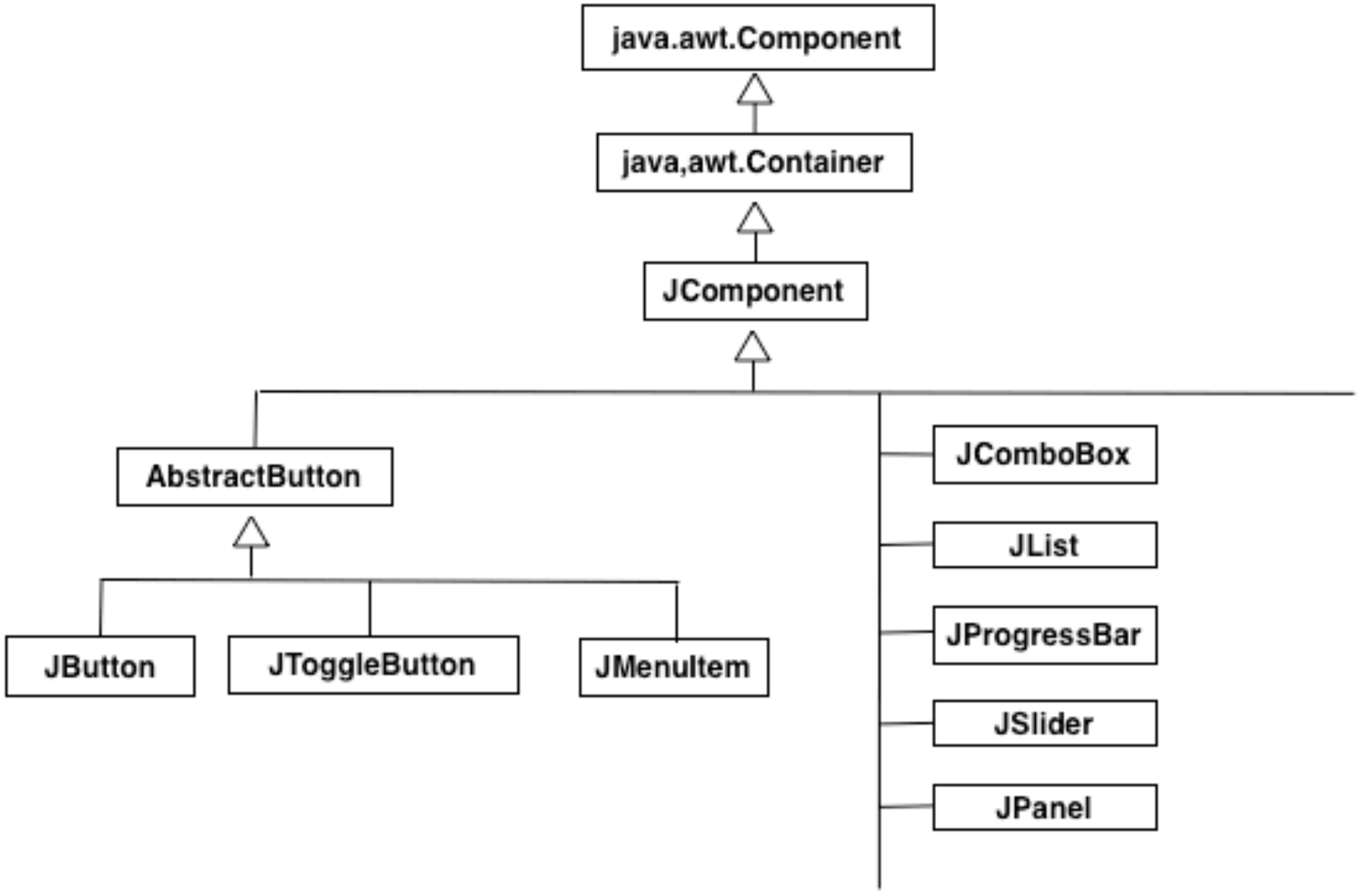
The java.awt package defines GUI components, containers and their layout managers.



NB: There are also many graphics classes to define colours, fonts, images etc.

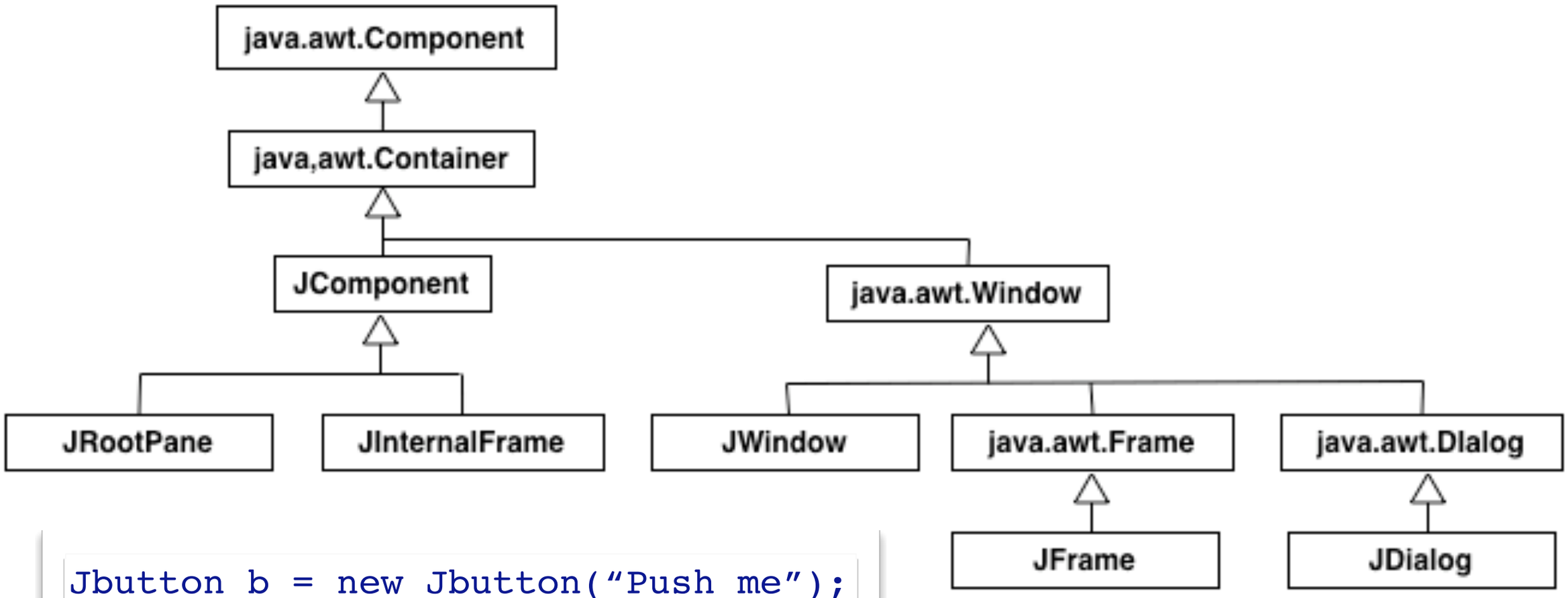
Swing JComponents

The javax.swing package defines GUI components that can adapt their “look and feel” to the current platform.



Swing Containers and Containment

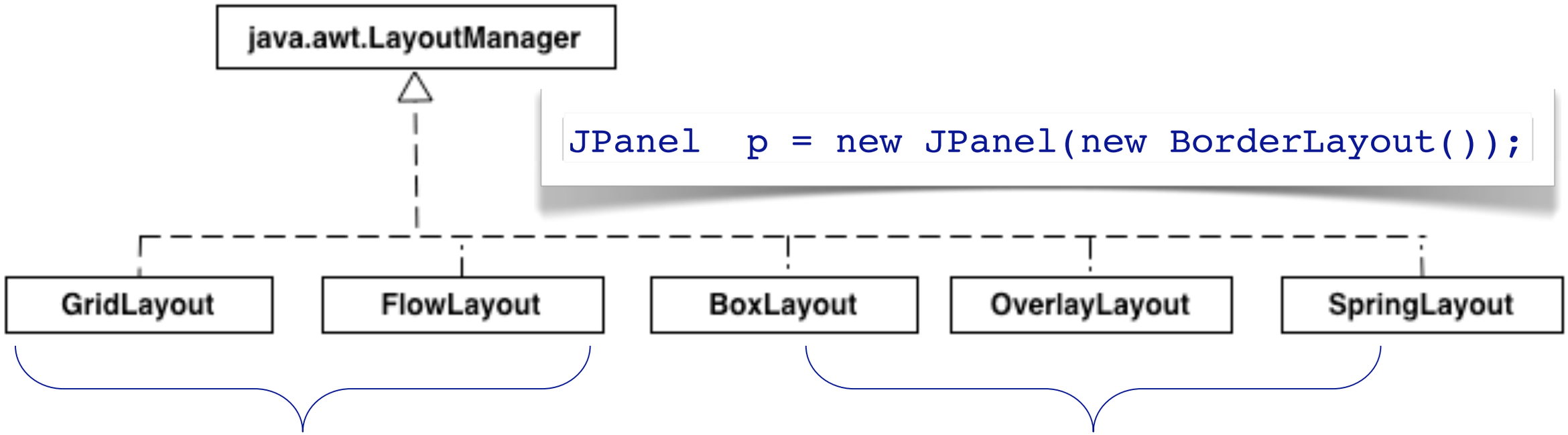
Swing Containers may contain other Components




```
Jbutton b = new Jbutton("Push me");
JPanel  p = new Jpanel();
p.add(b);
```

Layout Management

The Layout Manager defines how the components are arranged in a container (size and position).




```
JPanel  p = new JPanel(new BorderLayout());
```

awt LayoutManagers

swing LayoutManagers

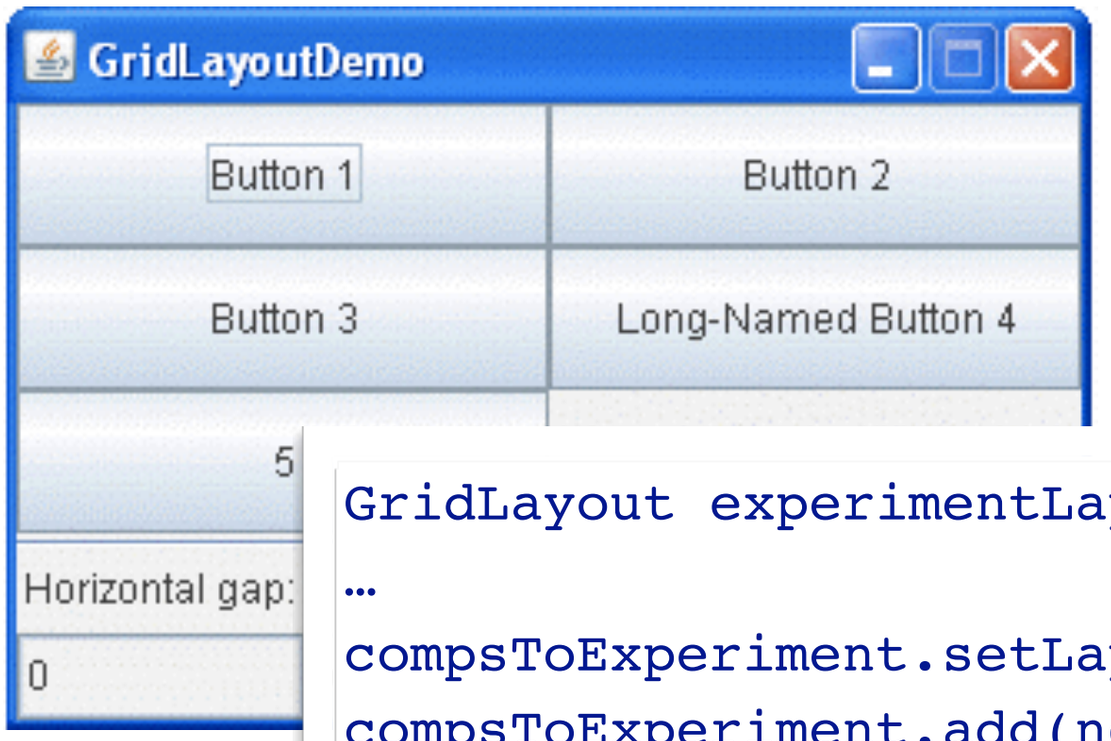
```
Container contentPane = frame.getContentPane();
contentPane.setLayout(new FlowLayout());
```

http://java.sun.com/docs/books/tutorial/uiswing/layout/using.html

An example: GridLayout

A GridLayout places components in a grid of cells.

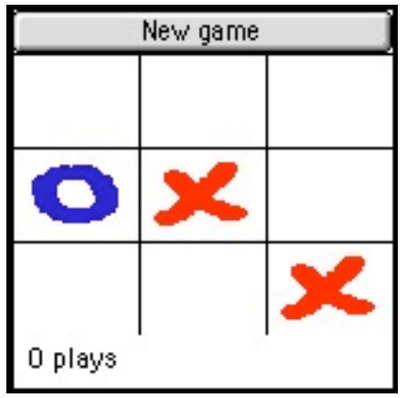
- Each component takes up all the space in a cell.
- Each cell is the same size

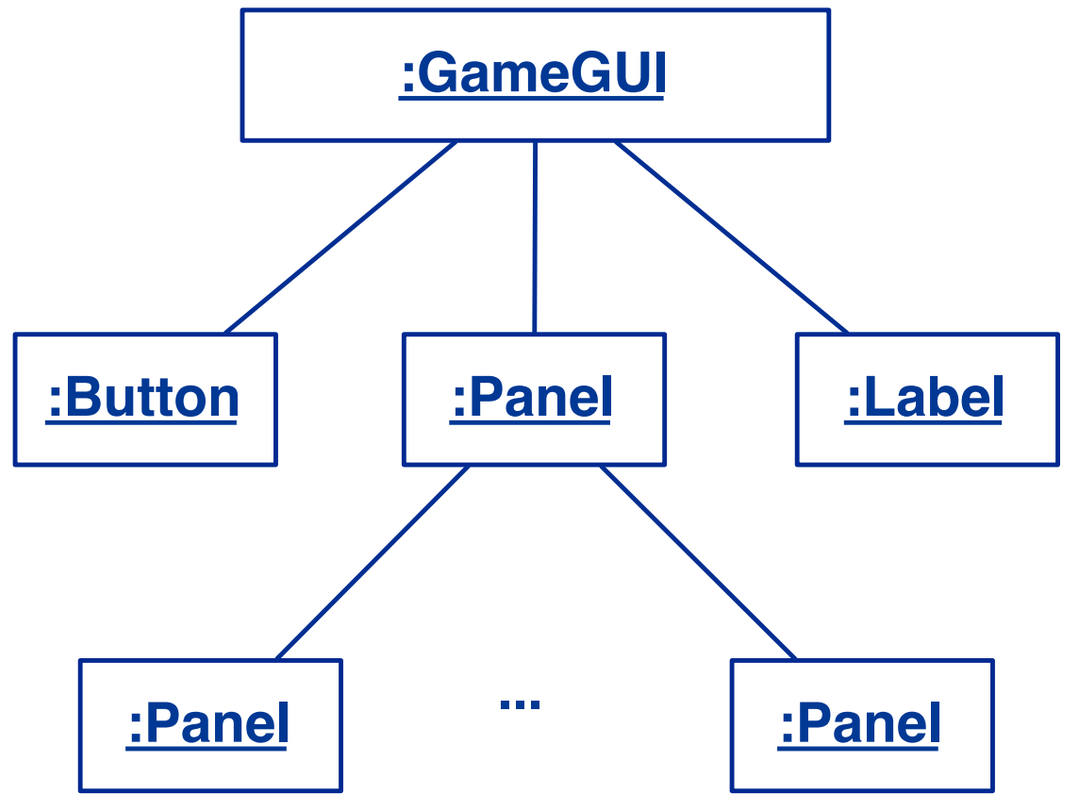



```
GridLayout experimentLayout = new GridLayout(0,2);
…
compsToExperiment.setLayout(experimentLayout);
compsToExperiment.add(new Jbutton(“Button 1”);
compsToExperiment.add(new Jbutton(“Button 2”);
```

The GameGUI

The `GameGUI` is a *`JFrame`* using a *`BorderLayout`* (with a centre and up to four border components), and containing a *`JButton`* (“North”), a *`JPanel`* (“Center”) and a *`JLabel`* (“South”).





The central Panel itself contains a grid of squares (Panels) and uses a `GridLayout`.

NB: *GameGUI and Place are the only classes that differ for AWT & Swing*

Laying out the GameGUI

```
public class GameGUI extends JFrame implements Observer {
    …
    public GameGUI(String title) throws HeadlessException {
        super(title);
        game = makeGame();
        …
        this.setSize(…);
        add("North", makeControls());
        add("Center", makeGrid());
        label = new JLabel();
        add("South", label);
        showFeedBack(game.currentPlayer().mark() + " plays");
        …
        this.show();
    }
```

TicTacToe v7-swing

Helper methods

As usual, we introduce helper methods to hide the details of GUI construction ...

```
private Component makeControls() {
    JButton again = new JButton("New game");
    ...
    return again;
}
```

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Interactivity with Events

- To make your GUI do something you need to handle *events*
  - —An event is typically a *user action* — a mouse click, key stroke, etc.
  - —The Java Event model is used by Java AWT and Swing (`java.awt.AWTEvent` and `javax.swing.event`)

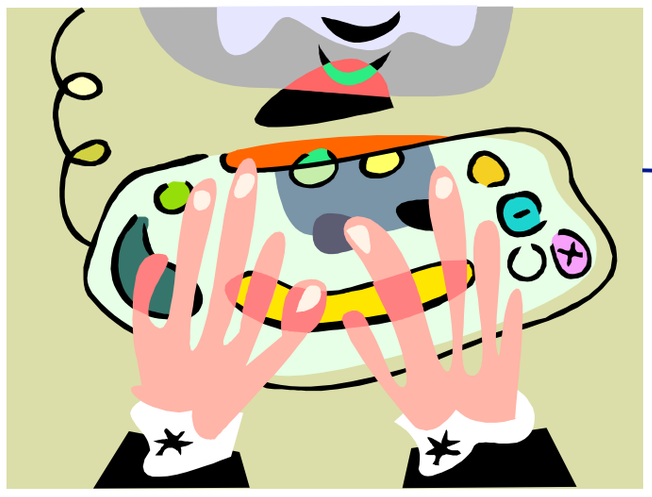
Concurrency and Swing

- The program is always responsive to *user interaction*, no matter what it is doing.
- The runtime of the Swing framework creates *threads* — you don't explicitly create them.
- The *Event Dispatch thread* is responsible for *event handling*.

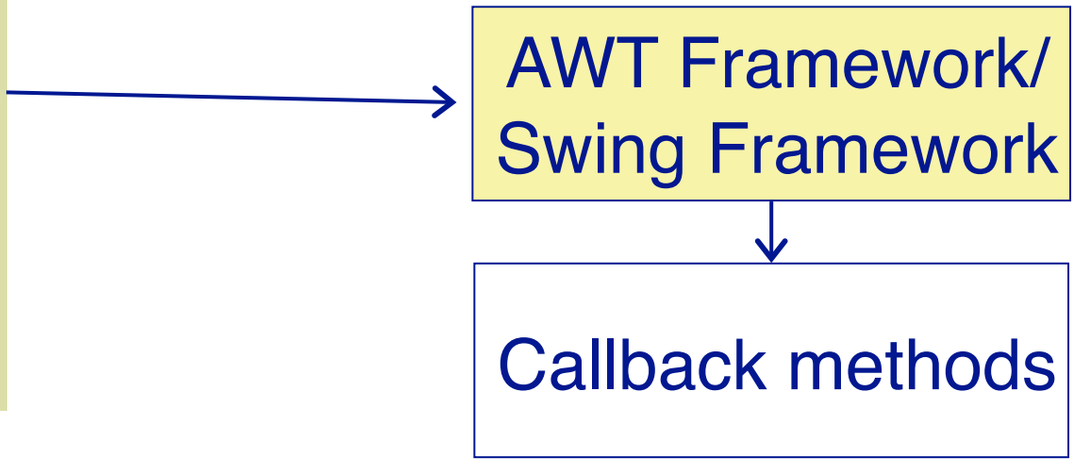
Events and Listeners (I)

Instead of actively checking for GUI events, you can define *callback methods* that will be invoked when your GUI objects receive events:

Hardware events ...
(`MouseEvent`, `KeyEvent`, ...)



... are handled by subscribed `Listener` objects



AWT/Swing Components *publish* events and (possibly multiple) Listeners *subscribe* interest in them.

http://java.sun.com/docs/books/tutorial/uiswing/events/index.html

Events and Listeners (II)

Every AWT and Swing component publishes a variety of different events (see java.awt.event) with associated Listener interfaces).

Component	*Events*	*Listener Interface*	*Listener methods*
JButton	**ActionEvent**	*ActionListener*	actionPerformed()
JComponent	**MouseEvent**	*MouseListener*	mouseClicked()
			mouseEntered()
			mouseExited()
			mousePressed()
			mouseReleased()
		MouseMotionListener	mouseDragged()
			mouseMoved()
	KeyEvent	*KeyListener*	keyPressed()
			keyReleased()
			keyTyped()
...			

Listening for Button events

When we create the “New game” `Button`, we *attach an* *`ActionListener`* with the `Button.addActionListener()` method:

```
private Component makeControls() {
    Button again = new Button("New game");
    again.addActionListener(new ActionListener() {
        public void actionPerformed(ActionEvent e) {
            showFeedBack("starting new game ...");
            newGame();                  // NB: has access to methods
        }                               // of enclosing class!
    });
    return again;
}
```

We instantiate an *anonymous inner class* to avoid defining a named subclass of `ActionListener`.

Gracefully cleaning up

A `WindowAdapter` provides an *empty implementation* of the `WindowListener` interface (!)

```
public class GameGUI extends JFrame implements Observer {
    …
    public GameGUI(String title) throws HeadlessException {
        …
        this.addWindowListener(new WindowAdapter(){
            public void windowClosing(WindowEvent e) {
                GameGUI.this.dispose();
                // NB: disambiguate “this”!
            }
        });
        this.show();
    }
```

Listening for mouse clicks

We also attach a `MouseListener` to each `Place` on the board.

```
private Component makeGrid() { ...
   Panel grid = new Panel();
   grid.setLayout(new GridLayout(3, 3));
   places = new Place[3][3];
   for (Row row : Row.values()) {
      for (Column column : Column.values()) {
         Place p = new Place(column, row);
         p.addMouseListener(new PlaceListener(p, this));
         ...
   return grid;
}
```

The PlaceListener

`MouseAdapter` is another convenience class that defines *empty* `MouseListener` methods

```
public class PlaceListener extends MouseAdapter {
   private final Place place;
   private final GameGui gui;
   public PlaceListener(Place myPlace, GameGUI myGui) {
      place = myPlace;
      gui = myGui;
   }
...
```

The PlaceListener ...

We only have to define the `mouseClicked()` method:

```
public void mouseClicked(MouseEvent e){
    ...
    if (game.notOver()) {
        try {
            ((GUIplayer) game.currentPlayer()).move(col,row);
            gui.showFeedBack(game.currentPlayer().mark() + " plays");
        } catch (AssertionException err) {
            gui.showFeedBack("Invalid move ignored ...");
        }
        if (!game.notOver()) {
            gui.showFeedBack("Game over -- " + game.winner() + " wins!");
        }
    } else {
        gui.showFeedBack("The game is over!");
    }
}
```

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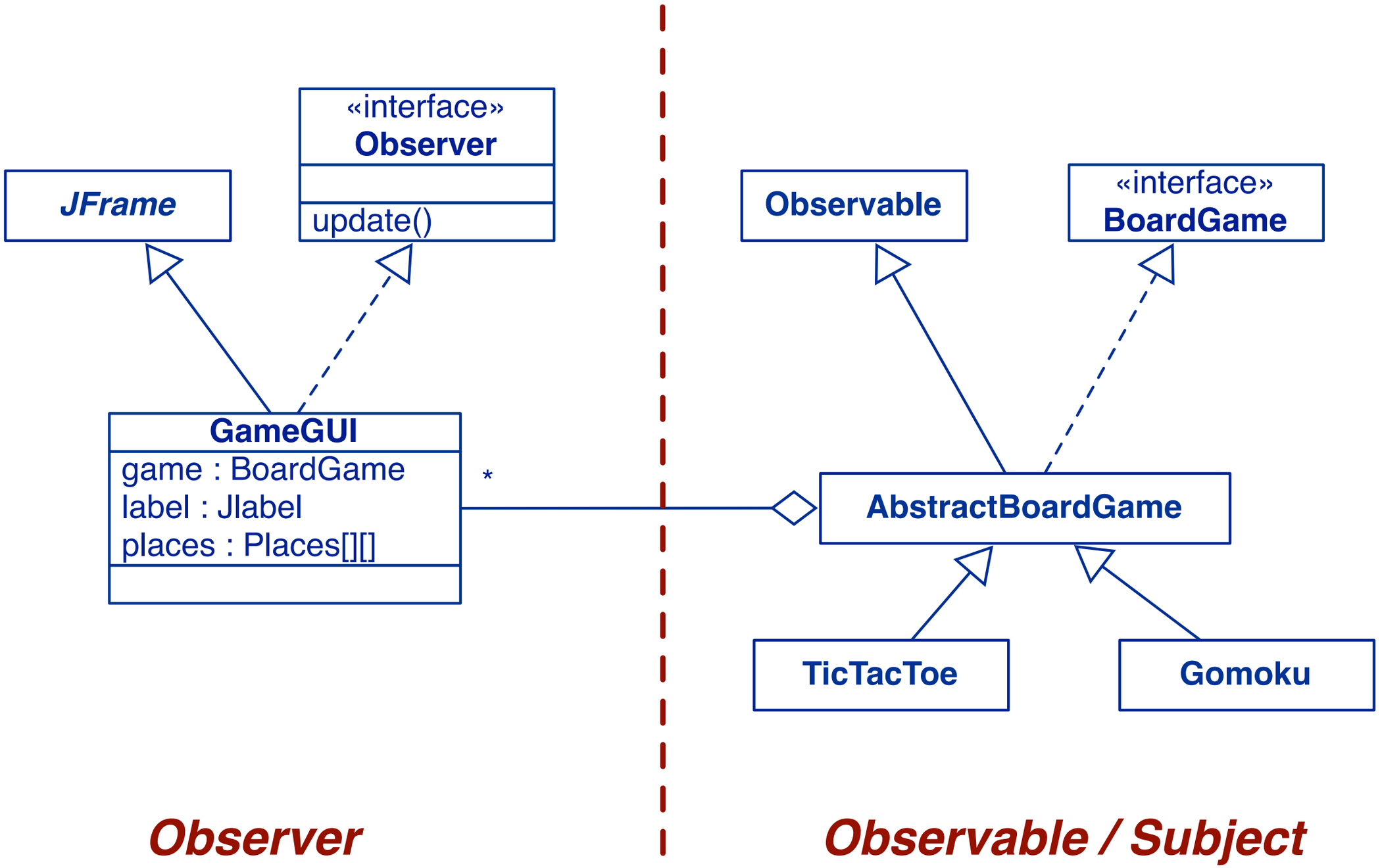
The Observer Pattern

- Also known as the *publish/subscribe* design pattern - to observe the state of an object in a program.
- One or more objects (called *observers*) are registered to *observe* an event which may be raised in an observable object (the *observable* object or *subject*).
- The the *observable* object or *subject* which may raise an event maintains a collection of *observers*.

Our BoardGame Implementation

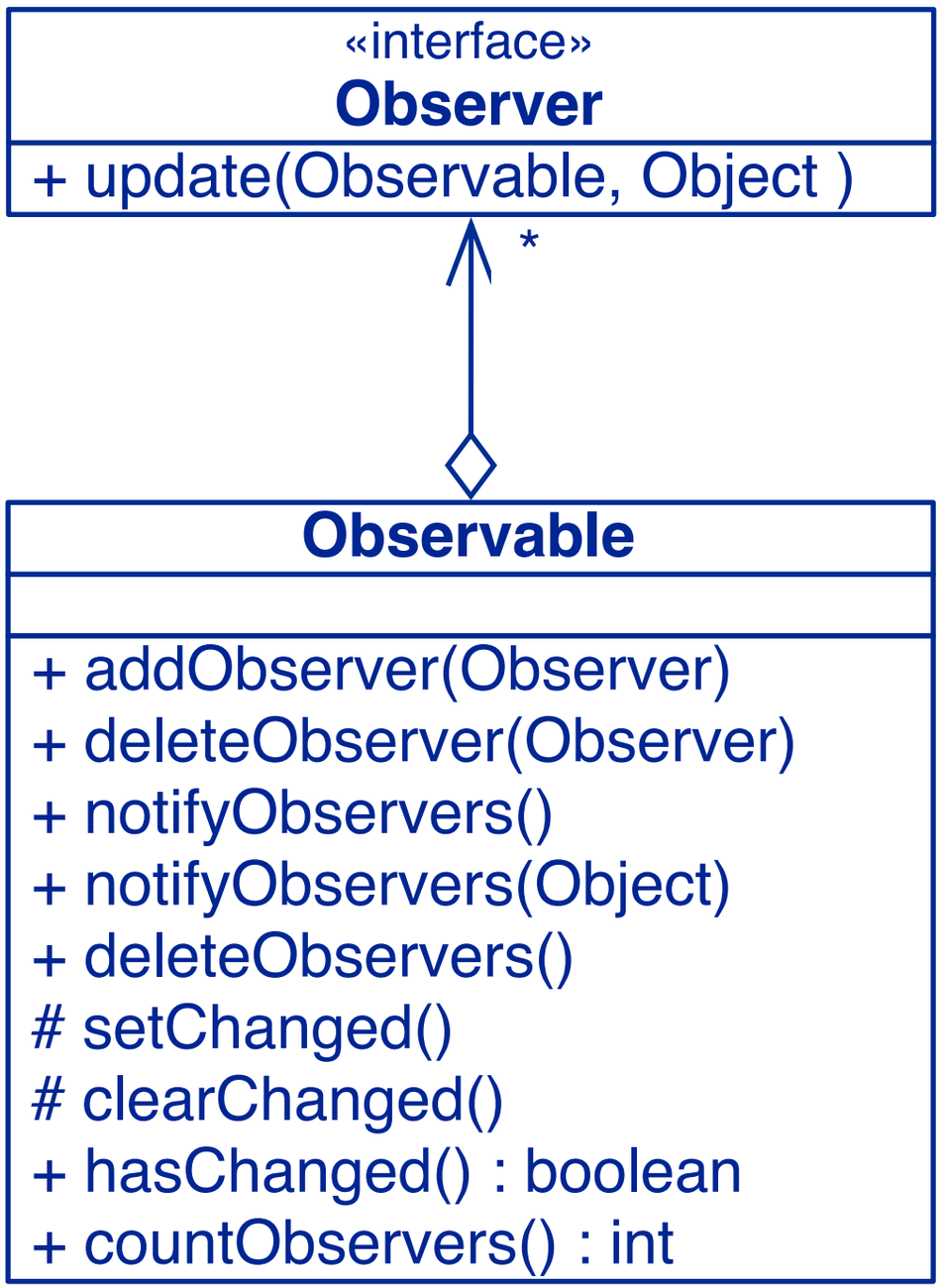


Observers and Observables

A class can implement the `java.util.Observer` interface when it wants to be informed of changes in `Observable` objects.

An `Observable` object can have *one or more Observers.*

After an observable instance changes, calling `notifyObservers()` causes all observers to be notified by means of their `update()` method.



Adding Observers to the Observable

```
public class GameGUI extends JFrame implements Observer
{
    ...
  public GameGUI(String title) throws HeadlessException {
    super(title);
    game = makeGame();
    game.addObserver(this); // notify GameGui if state change

...
```

Observing the BoardGame

In our case, the `GameGUI` represents a `View`, so plays the role of an `Observer of the BoardGame TicTacToe`:

```
public class GameGUI extends JFrame implements Observer
{
    ...
    public void update(Observable o, Object arg) {
        Move move = (Move) arg; // Downcast Object type
        showFeedBack("got an update: " + move);
        places[move.col][move.row].setMove(move.player);
    }
}
...
```

Observing the BoardGame ...

The `BoardGame` represents the *Model*, so plays the role of an `Observable` `(i.e. the subject being observed)`:

```
public abstract class AbstractBoardGame
   extends Observable implements BoardGame
{  ...
   public void move(int col, int row, Player p) {
      ...
      setChanged();
      notifyObservers(new Move(col, row, p));
   }
}
```

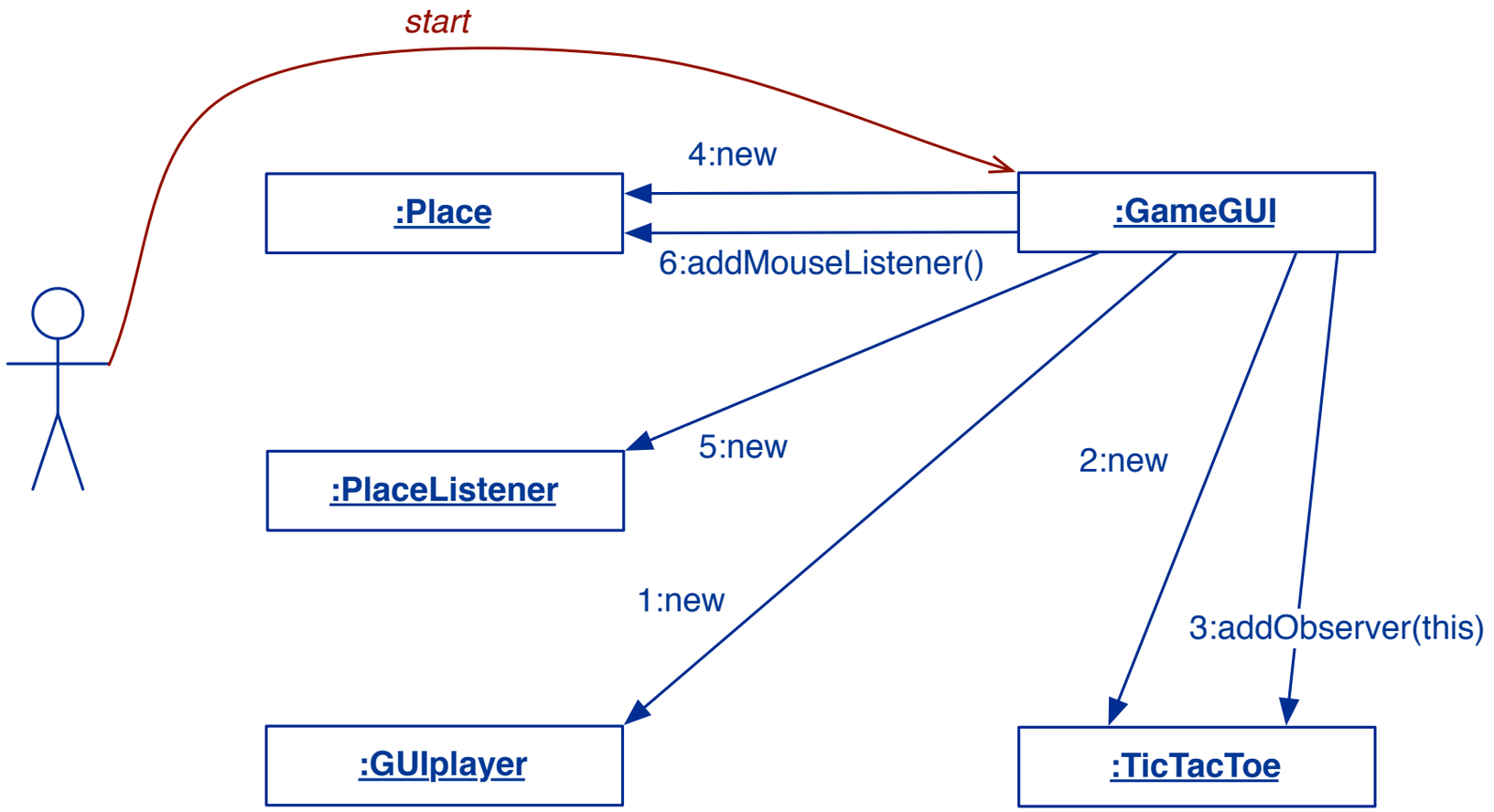
Handy way of Communicating changes

A `Move` instance bundles together information about a change of state in a `BoardGame`:

```
public class Move {
   public final int col, row;          // NB: public, but final
   public final Player player;
   public Move(int col, int row, Player player) {
      this.col = col; this.row = row;
      this.player = player;
   }
   public String toString() {
      return "Move(" + col + "," + row + "," + player + ")";
   }
}
```

Setting up the connections

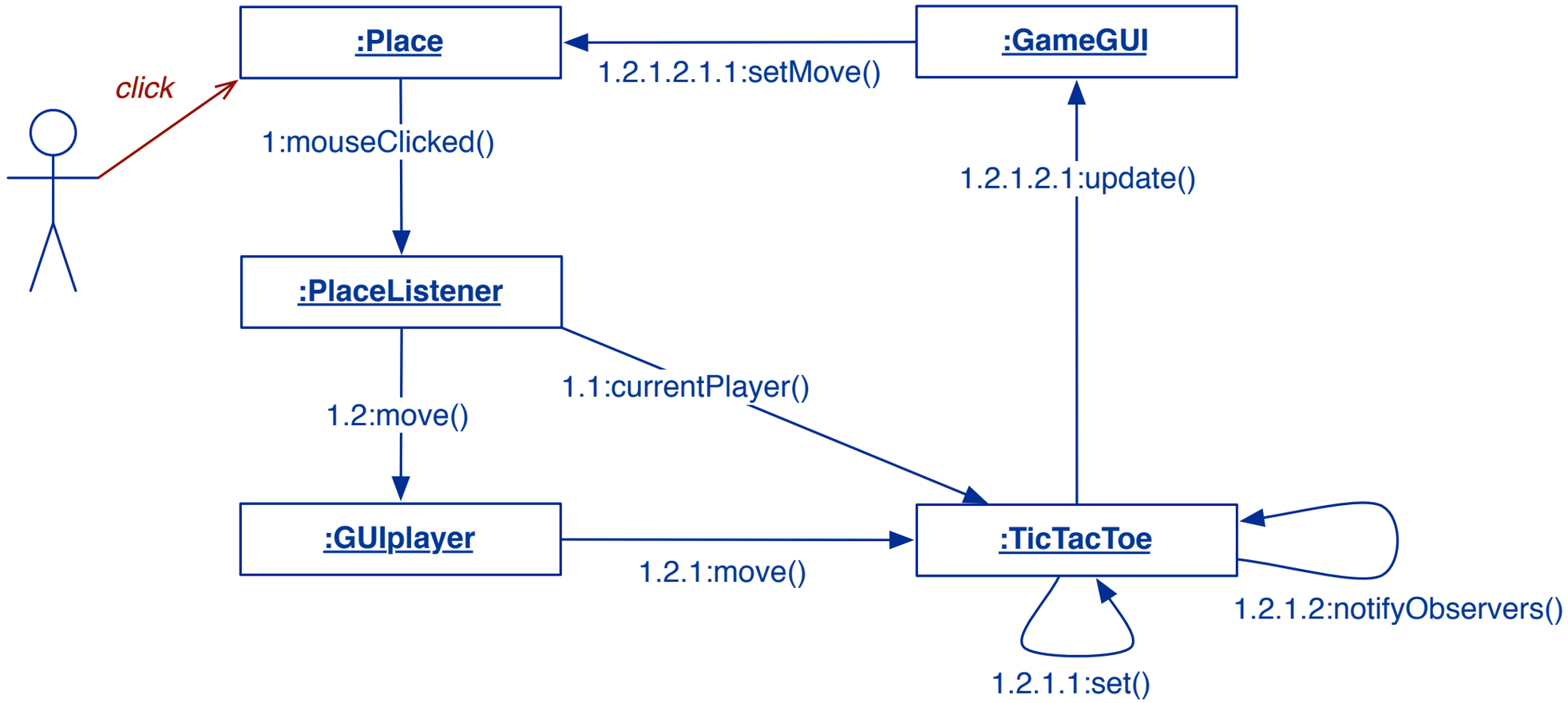
When the `GameGUI` is created, the *model (BoardGame), view (GameGui) and controller (Place)* components are instantiated.



The `GameGUI` *subscribes itself as an* `Observer` to the game (observable), and subscribes a `PlaceListener` to `MouseEvents` for each `Place` on the view of the `BoardGame`.

Playing the game

Mouse clicks are propagated from a `Place` *(controller)* to the BoardGame *(model):*



If the corresponding move is valid, the model's state changes, and the `GameGUI` updates the `Place` *(view).*

Checking user errors

- Assertion failures are generally a sign of errors in our program
  - However we cannot guarantee the user will respect our contracts!
  - We need special *always-on* assertions to check user errors

```
public void move(int col, int row, Player p)
    throws InvalidMoveException
{
    assert this.notOver();
    assert p == currentPlayer();
    userAssert(this.get(col, row).isNobody(),
                        "That square is occupied!");
    ...
}

private void userAssert(Boolean condition, String message)
    throws InvalidMoveException
{
    if (!condition) {
        throw new InvalidMoveException(message);
    }
}
```

Refactoring the BoardGame

Adding a GUI to the game affects many classes. We iteratively introduce changes, and *rerun our tests after every change ...*

- *Shift responsibilities* between `BoardGame` and `Player` (both should be passive!)
  - introduce `Player` interface, `InactivePlayer` and `StreamPlayer` classes
  - move `getRow()` and `getCol()` from `BoardGame` to `Player`
  - move `BoardGame.update()` to `GameDriver.playGame()`
  - change `BoardGame` to hold a matrix of `Player`, not marks
- Introduce *GUI classes* (`GameGUI`, Place, PlaceListener)
  - Introduce `GUIplayer`
  - `PlaceListener` triggers `GUIplayer` to move
- `BoardGame` must be *observable*
  - Introduce `Move class` to communicate changes from `BoardGame` to `Observer`
- Check user assertions!

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Jar files

We would like to bundle the Java class files of our application into a single, executable file

- A *jar* is a Java Archive
- The *manifest* file specifies the main class to execute

```
Manifest-Version: 1.0
Main-Class: tictactoe.gui.GameGUI
```

We could build the jar manually, but it would be better to automate the process …

(http://java.sun.com/docs/books/tutorial/deployment/jar/)

Ant

Ant is a Java-based make-like utility that uses XML to specify dependencies and build rules.

You can specify in a “build.xml”:

- the *name* of a project
- the *default target* to create
- the *basedir* for the files of the project
- *dependencies* for each target
- *tasks* to execute to create targets
- You can extend ant with your own tasks
- Ant is included in eclipse

(Each task is run by an object that implements a particular Task interface.)

(http://ant.apache.org/manual/index.html)

A Typical build.xml

```
<project name="TicTacToeGUI" default="all" basedir=".">
    <!-- set global properties for this build -->
    <property name="src" value="src"/>
    <property name="build" value="build"/>
    <property name="doc" value="doc"/>
    <property name="jar" value="TicTacToeGUI.jar"/>

    <target name="all" depends="jar,jdoc"/>

    <target name="init">
        <!-- Create the time stamp -->
        <tstamp/>
        <!-- Create the build directory structure used by compile -->
        <mkdir dir="${build}"/>
        <copy todir="${build}/tictactoe/gui/images">
            <fileset dir="${src}/tictactoe/gui/images"/>
        </copy>
        <mkdir dir="${doc}"/>
    </target>

    <target name="compile" depends="init">
        <!-- Compile the java code from ${src} into ${build} -->
        <javac srcdir="${src}" destdir="${build}"
            source="1.5" target="1.5"
            classpath="junit.jar" />
    </target>
```

...

...

```
    <target name="jdoc" depends="init">
        <!-- Generate the javadoc -->
        <javadoc destdir="${doc}" source="1.5">
        <fileset dir="${src}" includes="**/*.java"/>
        </javadoc>
    </target>

    <target name="jar" depends="compile">
        <jar jarfile="${jar}”
          manifest="${src}/tictactoe/gui/manifest-run" basedir="${build}"/>
    </target>

    <target name="run" depends="jar">
        <java fork="true" jar="${jar}"/>
    </target>

    <target name="clean">
        <!-- Delete the ${build} directory -->
        <delete dir="${build}"/>
        <delete dir="${doc}"/>
        <delete>
            <fileset dir="." includes="TicTacToeGUI.jar"/>
        </delete>
    </target>
</project>
```

Running Ant

```
% ant jar
Buildfile: build.xml
init:
    [mkdir] Created dir: /Scratch/P2-Examples/build
    [mkdir] Created dir: /Scratch/P2-Examples/doc
compile:
    [javac] Compiling 18 source files to /Scratch/P2-Examples/build
jar:
      [jar] Building jar: /Scratch/P2-Examples/TicTacToeGUI.jar
BUILD SUCCESSFUL
Total time: 5 seconds
```

Ant assumes that the build file is called build.xml

Javadoc

- Javadoc generates API documentation in HTML format for specified Java source files.
  - —Each class, interface and each public or protected method may be preceded by “javadoc comments” between /** and */.
  - —Comments may contain special tag values (e.g., @author) and (some) HTML tags.

Javadoc input

```
package p2.tictactoe;
/**
 * Minimal interface for Player classes that get moves from user
 * and forward them to the game.
 * @author $Author: oscar $
 * @version $Id: Player.java,v 1.5 2005/02/22 15:08:04 oscar Exp $
 */
public interface Player {
    /**
     * @return the char representation of this Player
     * @see AbstractBoardGame#toString
     */
    public char mark();
    …
}
```

Javadoc output

GUI objects in practice ...

Consider using Java webstart

> Download whole applications in a secure way

Consider other GUI frameworks (eg SWT from eclipse)

> org.eclipse.swt.* provides a set of native (operating system specific) components that work the same on all platforms.

Use a GUI builder

> Interactively build your GUI rather than programming it — add the hooks later. (e.g. http://jgb.sourceforge.net/index.php)

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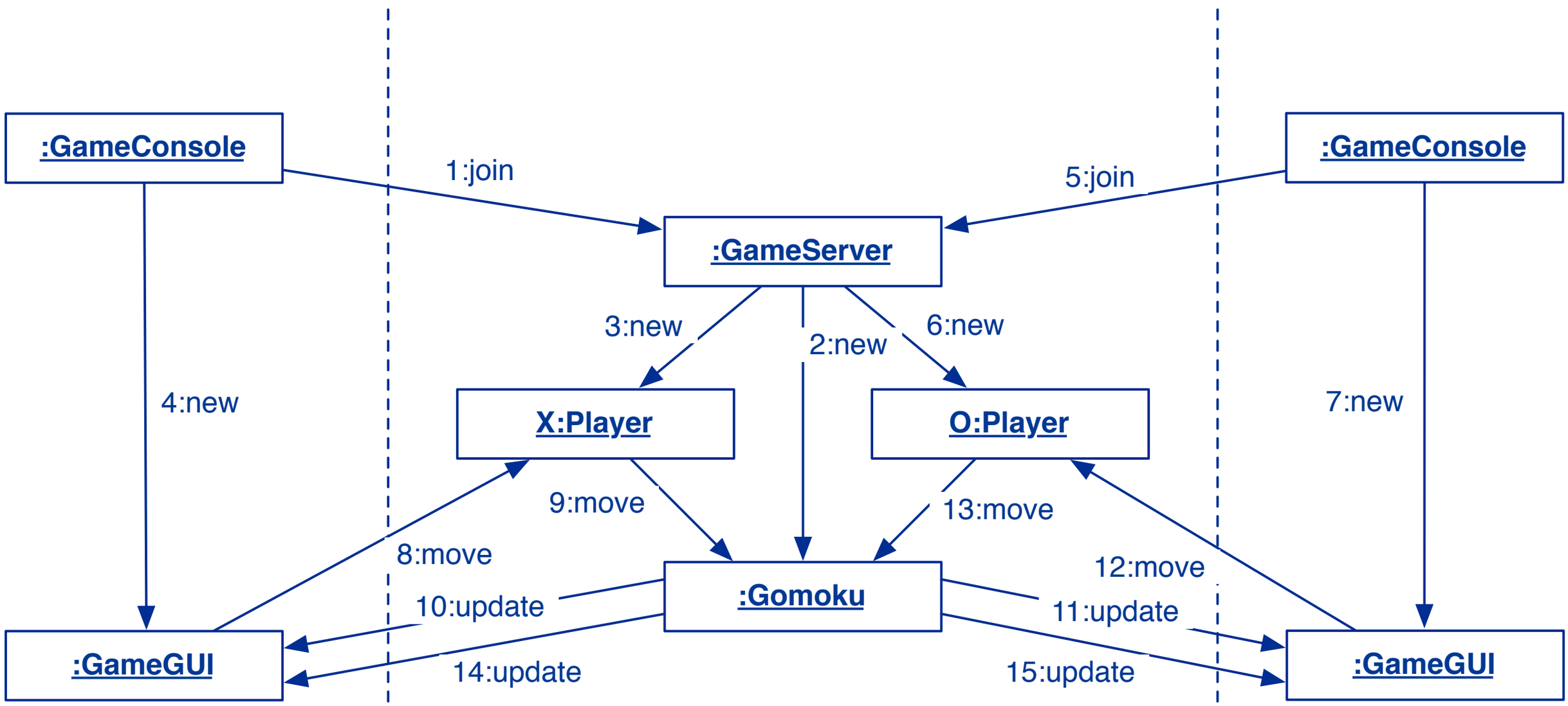
A Networked TicTacToe?

We now have a usable GUI for our game, but it still supports only a single user.

We would like to support:

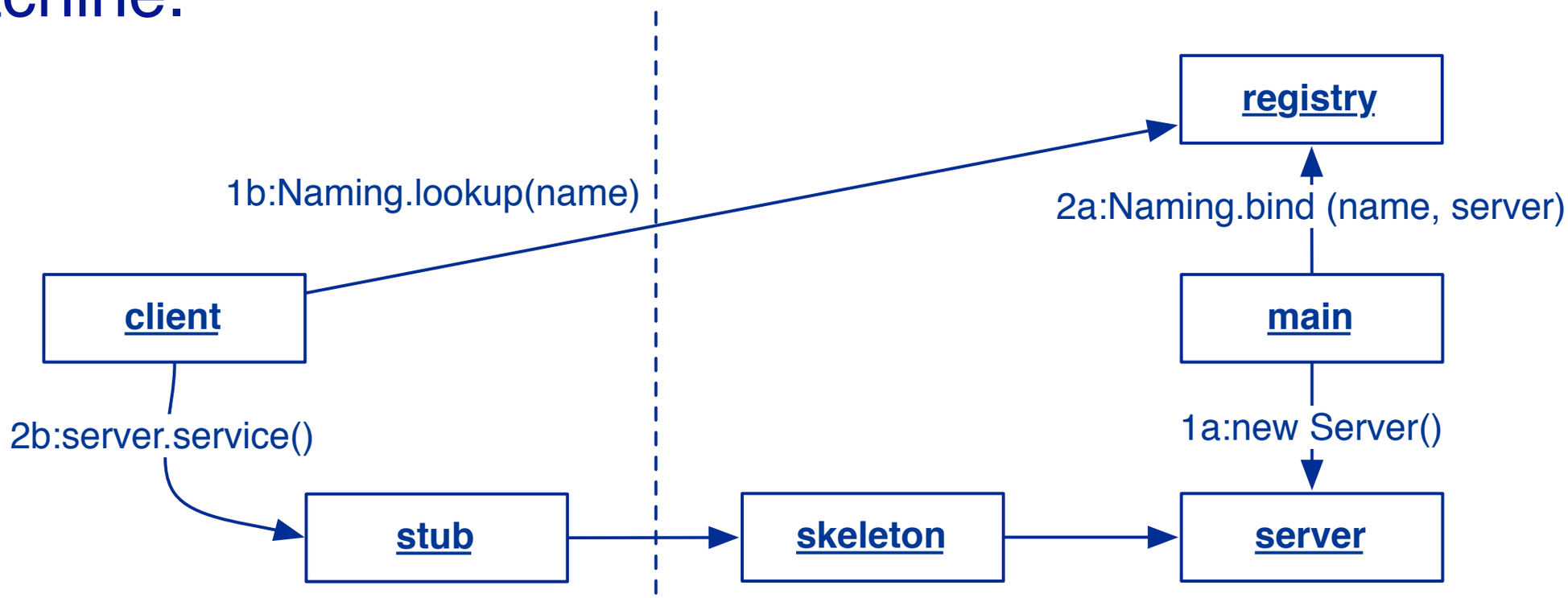
- players on *separate machines*
- each running the game GUI locally
- with a remote *"game server"* managing the state of the game

The concept


:GameConsole
1:join
:GameServer
5:join
:GameConsole
3:new
2:new
6:new
4:new
X:Player
O:Player
7:new
9:move
13:move
8:move
12:move
10:update
:Gomoku
11:update
:GameGUI
14:update
15:update
:GameGUI

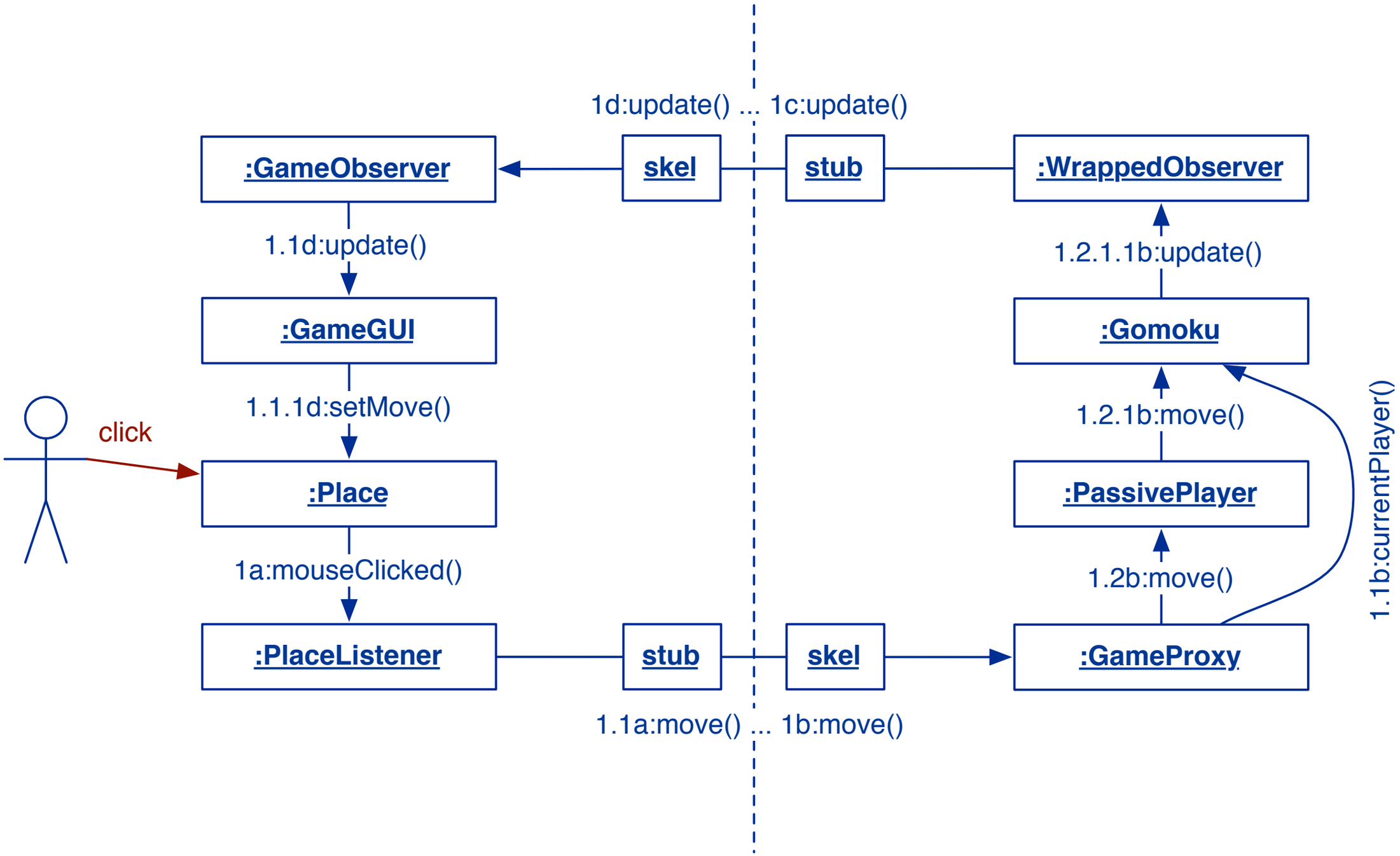
Remote Method Invocation

RMI allows an application to *register* a Java object under a *public name* with an *RMI registry* on the server machine.



A client may *look up* up the service using the public name, and obtain a local object (stub) that acts as a *proxy* for the remote server object (represented by a skeleton).

Playing the game



What you should know!

- *The TicTacToe game knows nothing about the GameGUI or Places. How is this achieved? Why is this a good thing?*
- *What are models, view and controllers?*
- *What is a Container,Component?*
- *What does a layout manager do?*
- *What are events and listeners? Who publishes and who subscribes to events?*
- *How does the Observer Pattern work?*
- *Ant*
- *javadoc*

Can you answer these questions?

- *How could you make the game start up in a new Window?*
- *What is the difference between an event listener and an observer?*
- *The Move class has public instance variables — isn't this a bad idea?*
- *What kind of tests would you write for the GUI code?*

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