Graphical User Interfaces (GUI)

Object Oriented Programming

http://softeng.polito.it/courses/09CBI

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Licensing Note

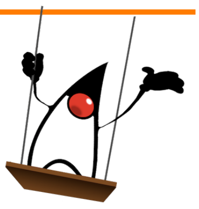
History

- Abstract Window Toolkit (AWT)
  - Original GUI API
  - Rely on native OS components
- Java Foundation Classes (JFC)
  - Announced in 1997
  - Part of JSK since Java 1.2
  - Includes: AWT, Swing (Widget toolkit), Java 2D
  - Lightweight
  - System independent

History

- JavaFX
  - Released in 2008 as a web-oriented framework
  - JavaFX 2.0 wider support (2012)
  - Part of JDK 8 (2014)
  - Oracle announce intention to not include JavaFX as part of JDK since Java 11 (September 2018)

JFC / Swing

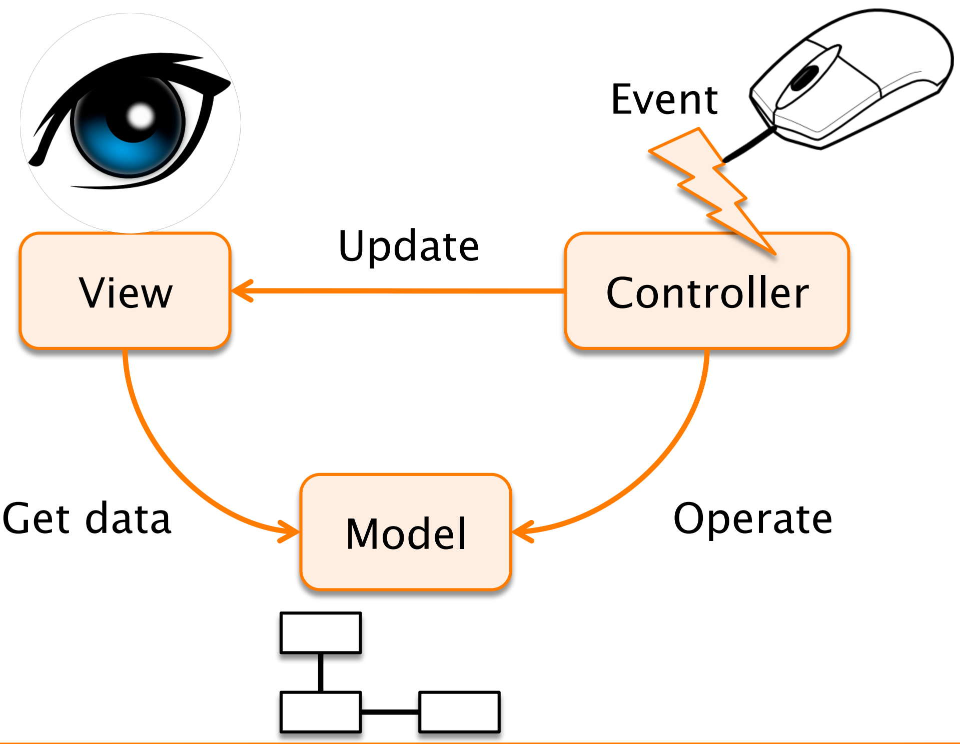


- Widget Toolkit
  - a widget (or control) is an element of a GUI that conveys information and/or represent a point of interaction
- Model-View-Controller pattern
- Pluggable look-and-feel

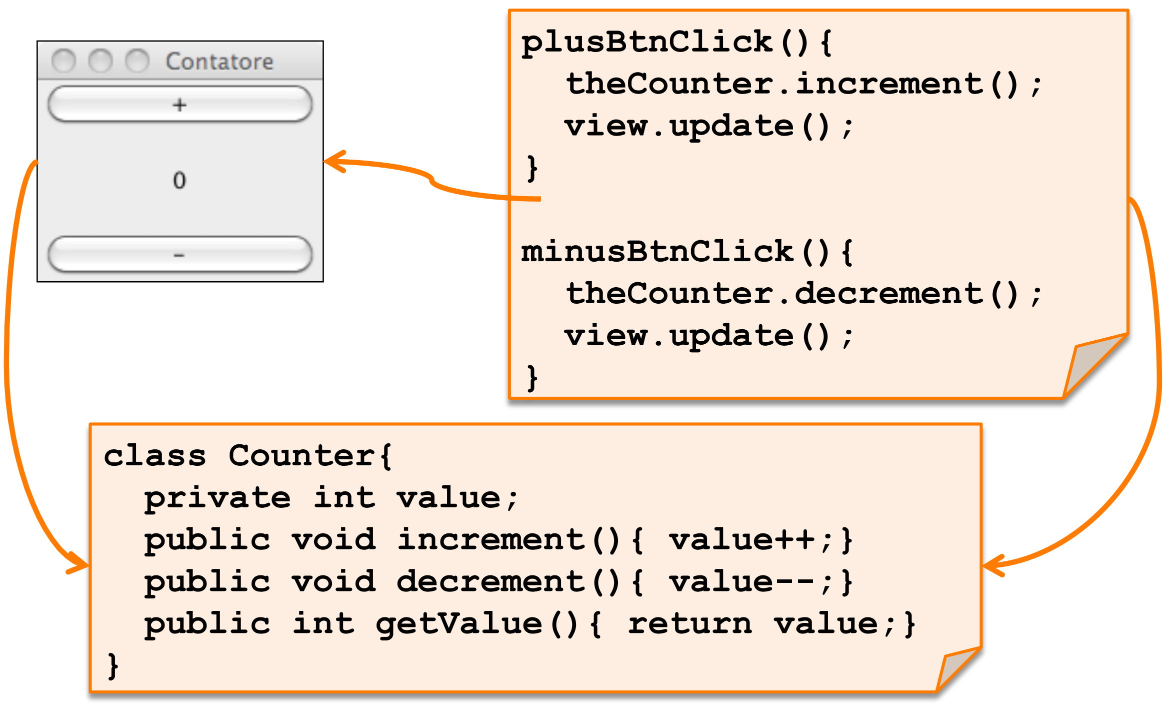
JavaFx

- Technology for rich client development
  - Seamlessly integrates several different capabilities
  - FXML: markup language for UI definition
  - New graphics pipeline (Prism)
  - New Toolkit (Glass)
  - Multimedia framework
  - Web component
  - Scene Builder

MVC



MVC example



```
plusBtnClick(){
  theCounter.increment();
  view.update();
}

minusBtnClick(){
  theCounter.decrement();
  view.update();
}
```

```
class Counter{
  private int value;
  public void increment(){ value++;}
  public void decrement(){ value--;}
  public int getValue(){ return value;}
}
```

MVC Principles

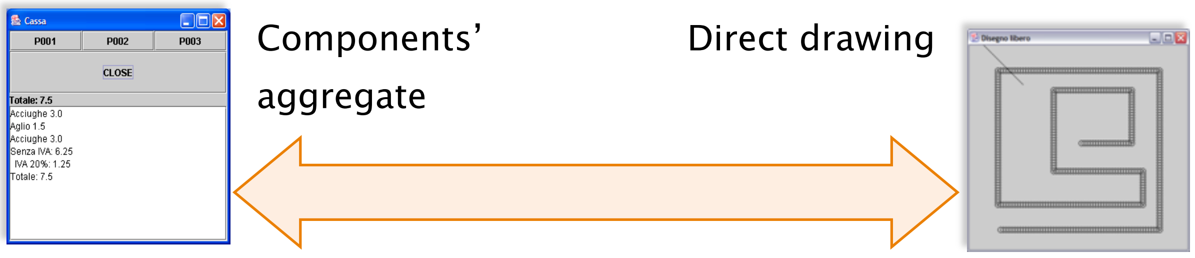
- When building a GUI we must consider two main aspects:
  - Layout (View): how to place the graphical elements to achieve a give visual aspect
  - Events (Controller): which behavior associate to elements' events
- Application logic (Model) must remain, as far as possible, separate from user interface.

Execution flow

- There is no predefined order of execution in GUI applications
  - Operation are performed in response to external events (e.g. mouse click)
  - Event handling is serialized
  - To execute several operations in parallel, threads must be used
- Method main in GUIs has the only goal of instantiating the graphical elements

GUI categories

- It is possible to identify two extreme types of GUIs:
  - Components' aggregate
  - Direct drawing
- A mix is often used in practice



```
Totale: 7.5
Acciughe 3.0
Aglio 1.5
Acciughe 3.0
Senza IVA: 6.25
 IVA 20%: 1.25
Totale: 7.5
```

GUI as Components' aggregate

- Use predefined UI components (widgets or controls)
  - E.g. buttons, text fields, labels
- They manage mostly textual information
  - Suitable to build an application that could "theoretically" make it with a textual user interface

GUI with drawing

- They directly access the screen
  - The tool is represented by the `Graphics` interface
  - They may use sophisticate API such as Java2D
- They manage visual information (e.g. diagrams, graphs, images)
- Typically are contained in a **`JPanel`** component

MAIN CONTAINER

Main GUI container

- Represents the point of interaction between Java and Operating System (OS)
- It may vary:
  - `JFrame` for desktop applications
  - `Applet` for web-enabled components
  - `Midlet` for JavaME (phone) applications
  - …

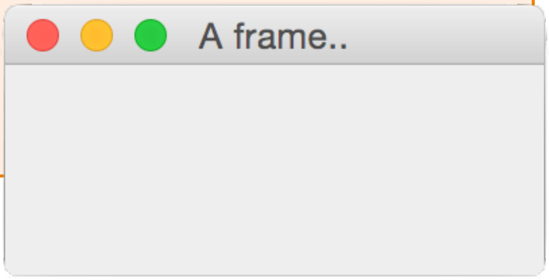
Frame container

- `JFrame` is the base class for desktop graphical applications
- Provides all the features for an empty window
  - Title bar
  - Standard buttons (Max, Min, Close)
  - Resizable border
  - Etc.

JFrame – Example

```
public class BasicFrame extends JFrame {
  public static void main(String[] args) {
   JFrame f = new BasicFrame();
   f.setVisible(true);
  }
  public BasicFrame(){
   super("A frame..");
   setSize(200,100);
  }
}
```

What happens without setSize() ?



Window close

- Clicking the button ☒ or ●
  - Closes the window but
  - Does not terminate the application
- It is required to explicitly define the operation to be performed in response to window closure

E.g.

```
setDefaultCloseOperation(
                        JFrame.DISPOSE_ON_CLOSE);
```

Container Basic Features

- `setDefaultCloseOperation(bhvr)`: define the behavior upon window close
  - `EXIT_ON_CLOSE`
  - `DO_NOTHING_ON_CLOSE`
  - `DISPOSE_ON_CLOSE`
  - `HIDE_ON_CLOSE`
- `setSize(int width, int height)`: defines the dimensions of the panel outside

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Application

- The main application has to
  - create a container (**`JFrame`**)
  - make it visible (starts a new event thread)

```
public class Minimal extends JFrame {
   public Minimal(){
      setTitle("Minimal UI");
      setSize(200,100);
      setDefaultCloseOperation(EXIT_ON_CLOSE);
   }
   public static void main(String[] args) {
      Minimal gui = new Minimal();
      gui.setVisible(true);
   }}
```

Could be moved into the ctor

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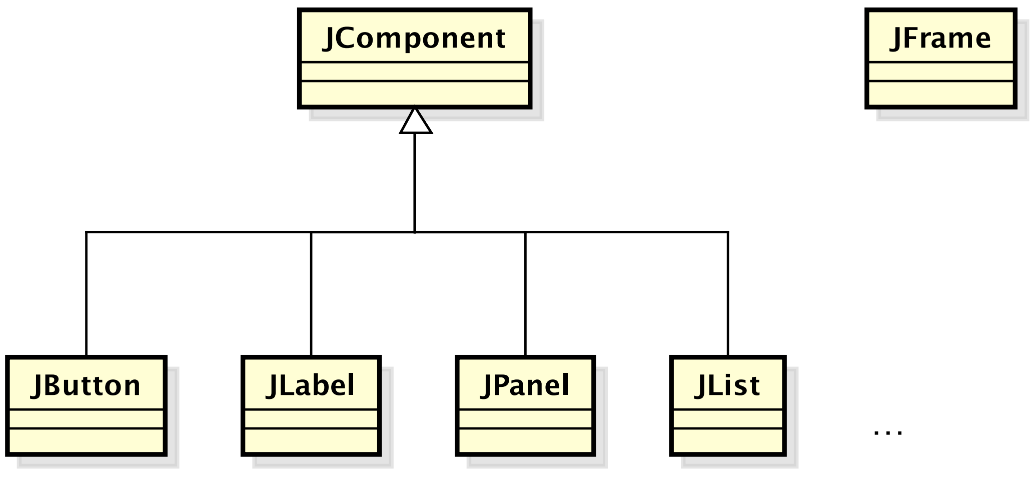
COMPONENTS

Main classes



Button: `JButton`

- Constructors:
  - `JButton();` creates a button without a text (without label)
  - `JButton(String);` creates a button with a label containing the text.
- it is a *component* → inherits all the methods of classes JComponent (javax.swing) and component (java.awt)
- It is a *container* → inherits all methods of java.awt.Container

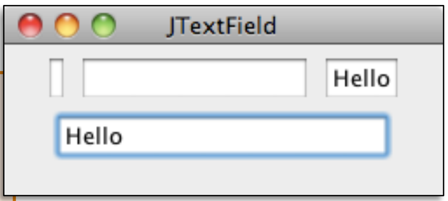
Label: `JLabel`

- Constructors
  - `JLabel(String);` create label with given text, aligned on the left
  - `JLabel(String, int);` create label with given text, aligned:
    - `SwingConstants.LEFT`
    - `SwingConstants.RIGHT`
    - `SwingConstants.CENTER`
- Available methods:
  - `getText(), setText(String)`
  - `getAlignement(), setAlignement(int)`

Text field: **`JTextField`**

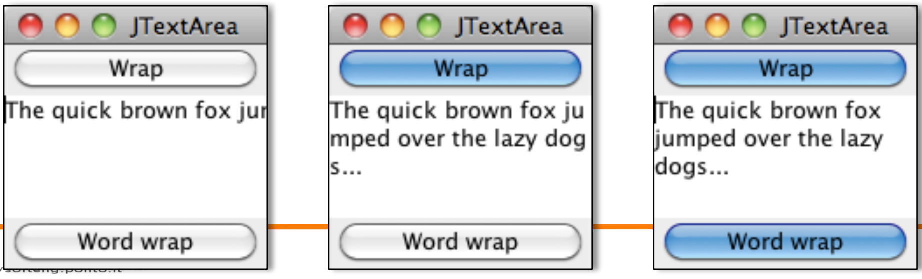
- The text fields allows entering strings of text on a single line
- Constructors:
  - **`JTextField(String)`** initial content
  - **`JTextField(int)`** required size in chars
  - …

```
add(new JTextField());
add(new JTextField("", 20));
add(new JTextField("Hello”));
add(new JTextField("Hello",30));
```



Text area: **`JTextArea`**

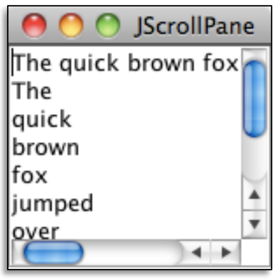
- Manages text on several lines
- Constructors
  - **`JTextArea (int lines, int columns)`**
  - **`JTextArea (String text, int l, int c)`**
- Useful Metods:
  - **`getText(), setText(String);`**
  - **`append(String), insert(String, int);`**
  - **`void setLineWrap(boolean)`**
  - **`void setWrapStyleWord(boolean)`**



Scrollpane: `JScrollPane`

- `JScrollPane` is able to add scroll bars to a scrollable component (e.g. `JTextArea`)
- Constructor:
  - `JScrollPane(Component );`
- Example:

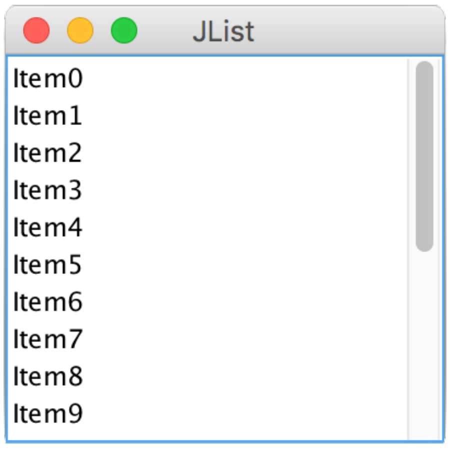
  -
    ```
    JScrollPane sp =
          new JScrollPane(
             new JTextArea(longText));
    ```



The quick brown fox
The
quick
brown
fox
jumped
over

Text field: `JList`

- The list show a set of items
- Constructors:
  - `Jlist()`
  - `JList(Object[] data)`
  - `JList(ListModel)` …
- Data can be defined using method
  - `setListData(…)`
- A scroll pane is often required



Item0
Item1
Item2
Item3
Item4
Item5
Item6
Item7
Item8
Item9

Checkbox, Options

- Check boxes : `JCheckBox(String, boolean)`
- Option buttons: `JRadioButton(String, boolean)`
- Useful methods:
  - `void setSelected(boolean)`
  - `boolean isSelected()`
- Mutual exclusion:
  - Add RadioButton (or CheckBox) to `ButtonGroup`
  - By default they are non-exclusive

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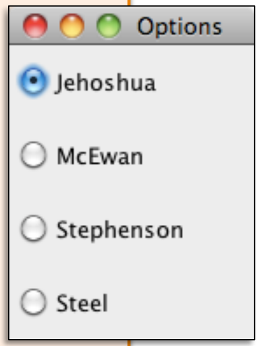
Example

```
public class Authors extends JFrame{
    JRadioButton[] list = new JRadioButton[4];
    public Authors() {
        super("Select an author");
        setSize(140, 190);
        setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        list[0] = new JRadioButton("Jehoshua", true);
        list[1] = new JRadioButton("McEwan");
        list[2] = new JRadioButton("Stephenson");
        list[3] = new JRadioButton("Steel");
        JPanel panel = new JPanel();
        ButtonGroup group = new ButtonGroup();
        for (int i = 0; i < list.length; i++) {
            group.add(list[i]);
            panel.add(list[i]);
        }
        setContentPane(panel);
        setVisible(true);
    }   public static void main (String args[]) {
        Authors newLista = new Authors(); }
}
```



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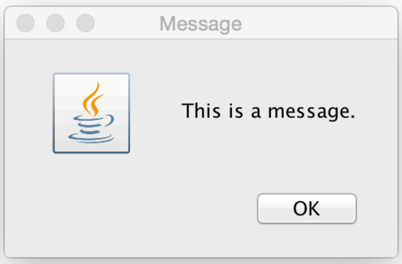
Dialog boxes

- Used for short focused interactions
  - Confirmation
  - Input
  - Message
  - Options
- Methods more efficient than input/ output in order to read from keyboard
- Class `JOptionPane`
  - Several static methods for different types

Dialog for confirmation

- Every dialog is dependent on a root Frame component.
  - Example:

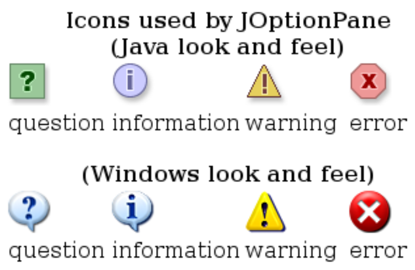
```
JOptionPane.showMessageDialog(frame,
                  "This is a message.");
```



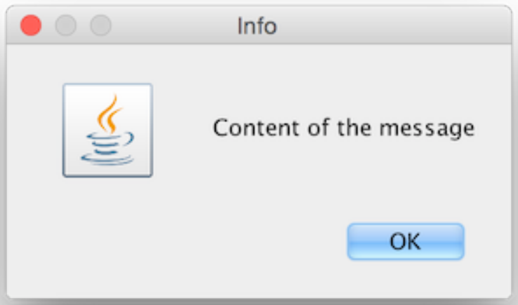
This is a message.

`JOptionPane` Features

- Using **`JOptionPane`**, you can quickly create and customize several different kinds of dialogs. **`JOptionPane`** provides support for laying out standard dialogs, providing icons, specifying the dialog title and text, and customizing the button text.

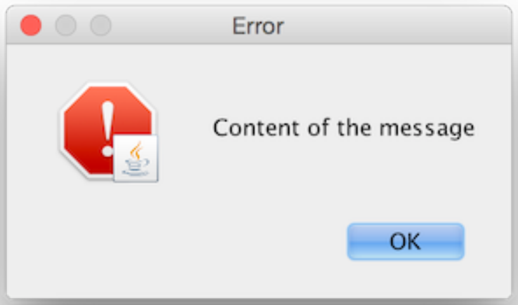


Message dialog types


Info

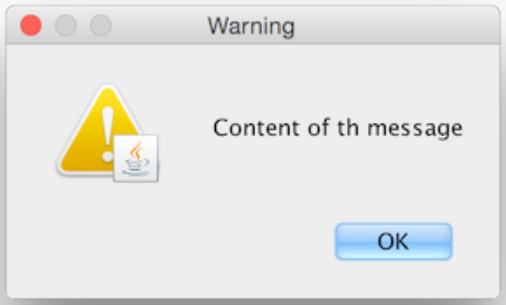
Content of the message

`INFORMATION_MESSAGE` (default)


Error

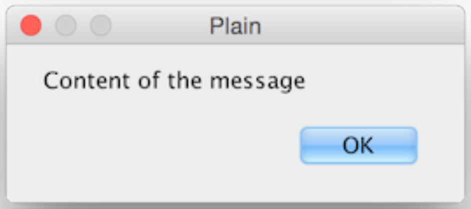
Content of the message

`ERROR_MESSAGE`


Warning

Content of th message

`WARNING_MESSAGE`


Plain

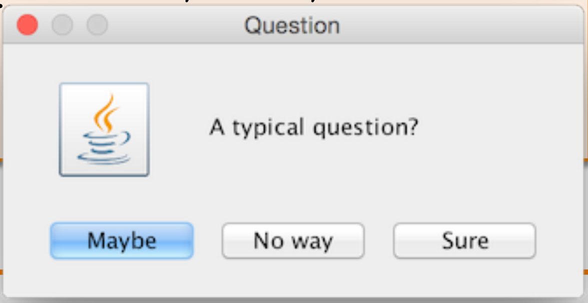
Content of the message

`PLAIN_MESSAGE`

Option dialog

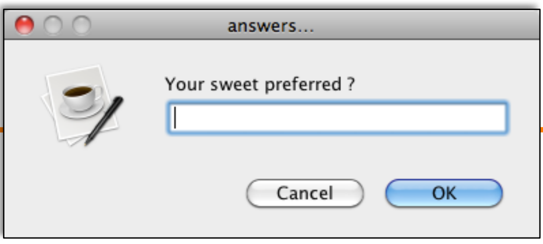
- Presents used with a few choices

```
String[] options={"Sure","No way","Maybe"};
JOptionPane.showOptionDialog(null,
"A typical question?",
"Question",
JOptionPane.YES_NO_CANCEL_OPTION,
JOptionPane.QUESTION_MESSAGE,null,
Options,
options[1]);
```



A typical question?

Input dialog



Your sweet preferred ?

- `String showInputDialog(Component, Object)`
- `String showInputDialog(Component, Object, String, int)`
  - Component: in which component appears window
  - Object: Request message input
  - String: title
  - int: type of message (as in confirmation)

```
String answer =
  JOptionPane.showInputDialog(null,
  "Your sweet preferred ?", "answers...",
  JOptionPane.QUESTION_MESSAGE);
```

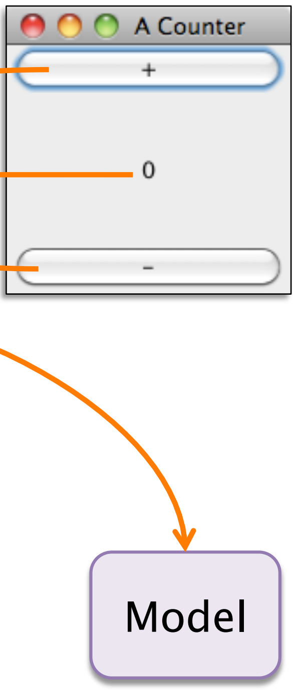
Full example: visual counter

- Model: a simple counter

```
public class Counter {
  private int value;
  public void increment(){
    value++;
  }
  public void decrement(){
     value--;
  }
  public int getValue(){
    return value;
  }
}
```

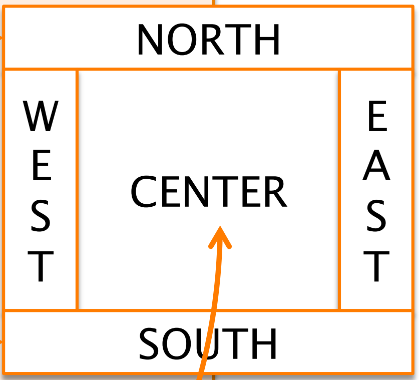
Visual Counter – View

```
public class View extends JFrame {
  private JButton plus;
  private JLabel value;
  private JButton minus;
  private Counter model;
  public View(Counter c,
              Controller controller){
  … }
  public void update(){
  … }
}
```



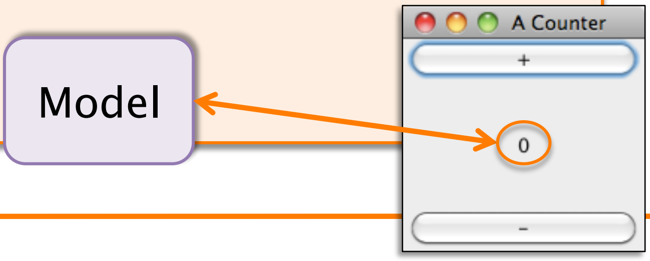
Visual Counter – View

```
public class View extends JFrame {
public View(Counter c, Controller controller){
   setTitle("A Counter");
   setSize(150,150);
   setLayout(new BorderLayout());
   plus = new JButton("+");
   this.add(plus,BorderLayout.NORTH);
   minus = new JButton("-");
   this.add(minus,BorderLayout.SOUTH);
   value = new JLabel("?");
   value.setHorizontalAlignment(JLabel.CENTER);
   this.add(value,BorderLayout.CENTER);
   setVisible(true);
```



Visual Counter – View

```
   setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);
   model = c; // MODEL
   plus.addActionListener(controller);
   minus.addActionListener(controller);
   controller.setView(this); // CONTROLLER --> VIEW
   update();
}
public void update(){
   String v = Integer.toString(model.getValue());
   value.setText(v);
}
```



Visual Counter – Controller

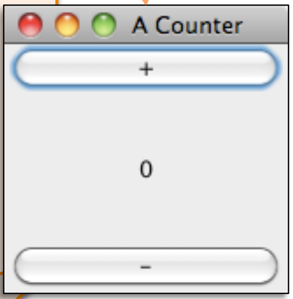
```
public class Controller
      implements ActionListener {
  private Counter model;
  private View view;

  public Controller(Counter m){ model = m; }

  public void actionPerformed(ActionEvent e){
    if(e.getActionCommand().equals("+")){
      model.increment();
    else
      model.decrement();
    view.update();
  }

  public void setView(View finestra) {
    view = finestra;
  }
}
```

Model



LAYOUT

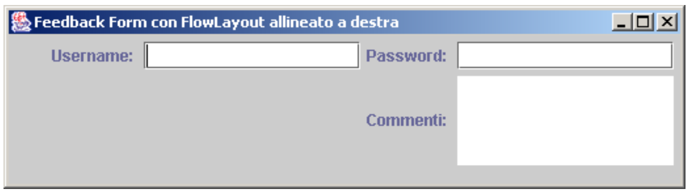
Layout managers

- Determine the size and position of the components within a container
  - Manage resize of containers
  - Accounts for differences in OSs and font sizes
- **`setLayout(LayoutManager m);`**
- Absolute positioning is possible
  - **`setLayout(null);`**
  - **`setBounds()`** for each component

Flow Layout

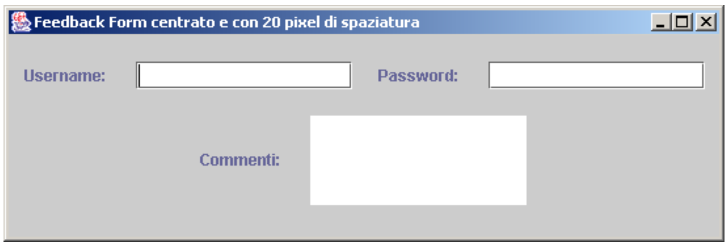
- From left to right, starting from the left upper corner
- Constructors:
  - **`FlowLayout();`**
  - **`FlowLayout(int align);`**
  - **`FlowLayout(int align, int hgap, int vgap);`**
- Parameters:
  - **`align`**: Alignment of basis (**`FlowLayout.LEFT`**, **`FlowLayout.RIGHT`**, **`FlowLayout.CENTER`**)
  - **`hgap`**: Horizontal space between components (default: 3 px)
  - **`vgap`**: Vertical space between components (default: 3 px)

Example of FlowLayout


Feedback Form con FlowLayout allineato a destra

(FlowLayout.RIGHT)

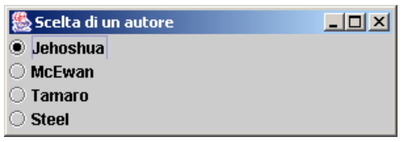
(FlowLayout.CENTER,20,20)


Feedback Form centrato e con 20 pixel di spaziatura

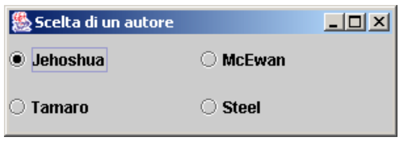
Grid Layout

- Splits the screen in a grid of rows and columns
- Filling: starts from the box in the top left and then by line
- Constructors:
  - `GridLayout(int rows, int cols)`
  - `GridLayout(int rows,int cols,int hgap,int vgap)`
- Parameters:
  - **`rows`**: number of row;
  - **`cols`**: number of columns;
  - **`hgap`**: Spacing (in pixels) between two horizontal boxes (default: 0 pixel)
  - **`vgap`**: spacing (in pixel) between two vertical boxes (default: 0 pixel)

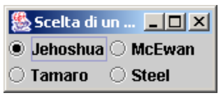
Example of GridLayout



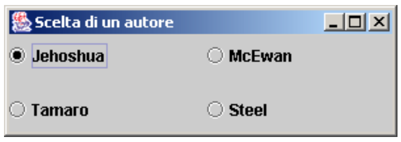
4 row, 1 columns:
distance 0



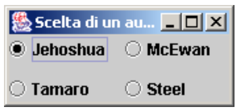
2 row, 2 columns:
distance 0 pixel



(Distanza min = 0)



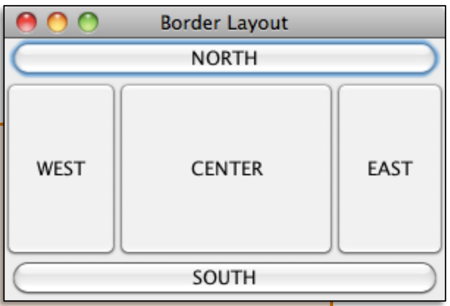
2 row, 2 columns:
distance 10 pixel



(Min distance = 10)

BorderLayout

- Divide the container into five areas
  - 4 in the border 1 in the center



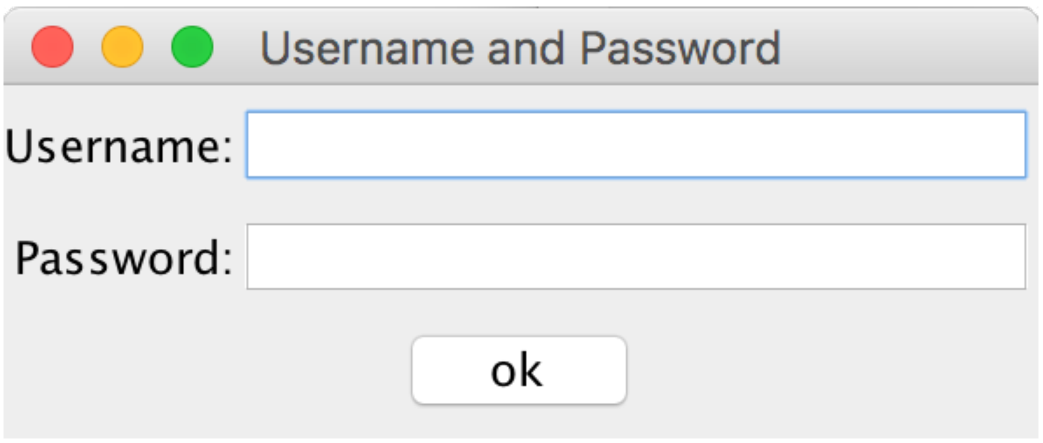
```
setLayout(new BorderLayout());
add("North",new JButton("NORTH"));
add("South",new JButton("SOUTH"));
add("East",new JButton("EAST"));
add(new JButton("WEST"),BorderLayout.WEST);
add(new JButton("CENTER"),BorderLayout.CENTER);
```

Grid bag layout

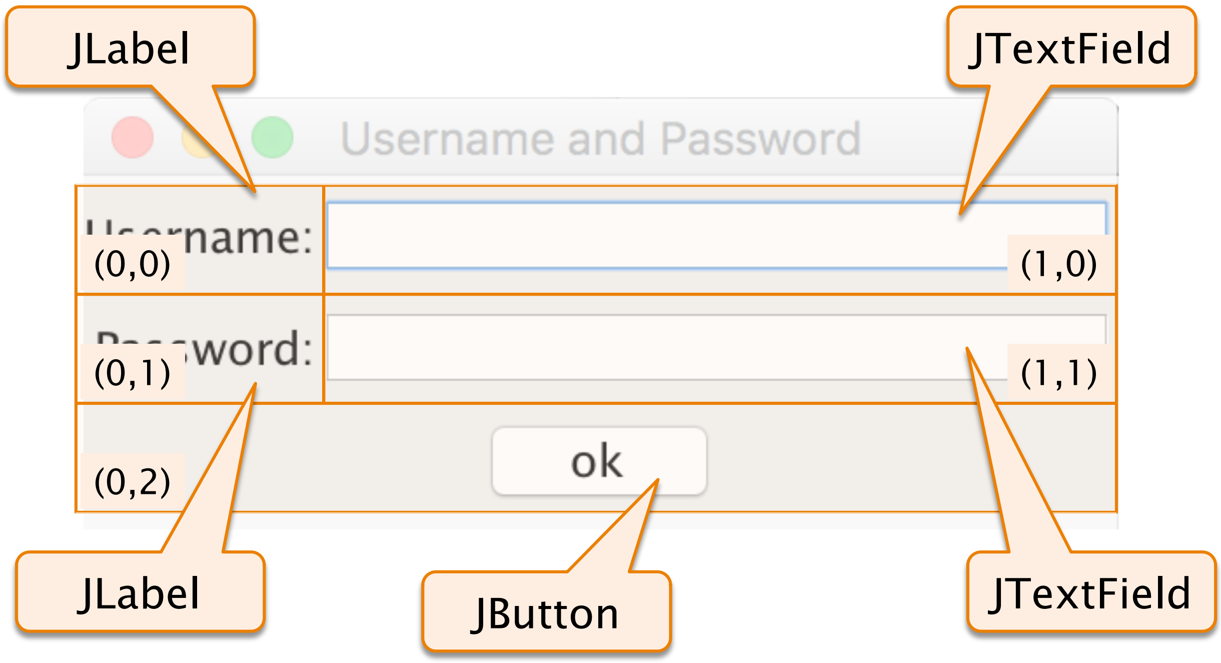
- Extension of the grid layout (GridLayout)
  - elements of the grid can be adjusted with mechanisms of personalization
- Usage:
  - Create `GridBagLayout` object
  - Create '*constraint*' object (`GridBagConstraints`)
  - For each component
    - Define the adjustment
    - Register the component-constraint link with the manager
  - Add the component to the container

Example

- Structure required to render a simple login window such as:



`GridBagConstraints` details



Rules expressed as constraints

- Components are placed in the cells at position (x, y)
- "OK" button must occupy two cells: the other components are in a single cell
- breadth of the components is variable (the label "name" occupies about 30% of line…)
- Cells are positioned (the "OK" button is centered, etc.)

Rules on **GridBagConstraints** (2)

- **GridBagConstraints** has the fields:
  - `gridx` – The initial gridx value.
  - `gridy` – The initial gridy value.
  - `gridwidth` – The initial gridwidth value.
  - `gridheight` – The initial gridheight value.
  - `weightx` – The initial weightx value.
  - `weighty` – The initial weighty value.
  - `anchor` – The initial anchor value.
  - `fill` – The initial fill value.
  - `insets` – The initial insets value.
  - `ipadx` – The initial ipadx value.
  - `ipady` – The initial ipady value.

Regulation on **GridBagConstraints** (3)

- The values of `fill` are : **BOTH**, **NONE**, **HORIZONTAL**, **VERTICAL**
- The values of **anchor** are: **CENTER**, **NORTH**, **NORTHEAST**, **EAST**, **SOUTHEAST**, **SOUTH**, SOUTHWEST, **WEST**, **NORTHWEST**
- Therefore…

```
GridBagLayout grid = new GridBagLayout();
pannel.setLayout(grid);
GridBagConstraints Gbc = new GridBagConstraints();
JLabel label1 = new JLabel ("Name:", JLabel.LEFT);
    Gbc.gridx = 0;
    Gbc.gridy = 0;
    Gbc.gridwidth = 1;
    Gbc.gridheigth = 1;
    Gbc.weightx = 30;
    Gbc.weigthy = 40;
    Gbc.fill = GridBagConstraints.NONE;
    Gbc.anchor = GridBagConstraints.EAST;
grid.setConstraints(Gbc, label1);
pannello.add(label1);
```

JAVA EVENTS

Event Delegation Model

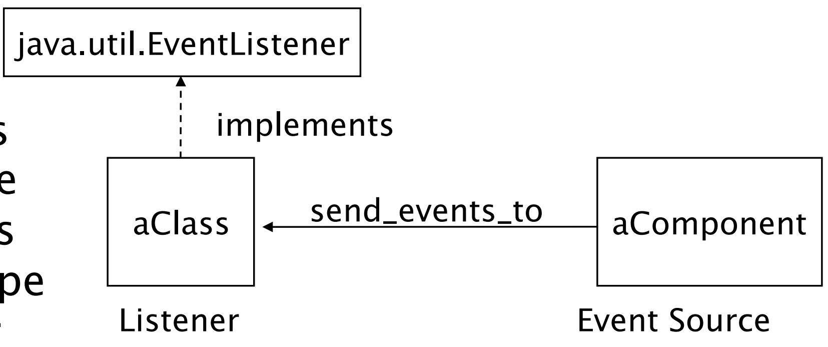
- Since Java1.1
  - Events are classified by type (MouseEvent, KeyEvent, etc.)
  - Events are generated in components sources
  - An object can be registered as handler (listener) of a type of event by sending a message to the component source

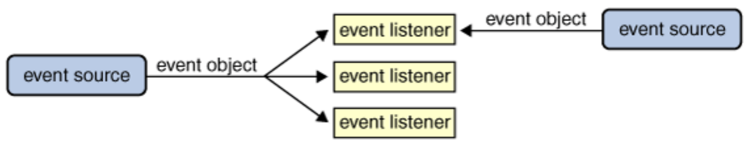
Event Delegation Model

- Whenever an event occurs, the UI thread sends a message to all the registered listener objects (the event descriptor is passed as a parameter)
- A listener object must implement the appropriate interface (to allow the call-back)

Event Delegation Model

Multiple listeners can register to be notified of events of a particular type from a particular source. Also, the same listener can listen to notifications from different objects.

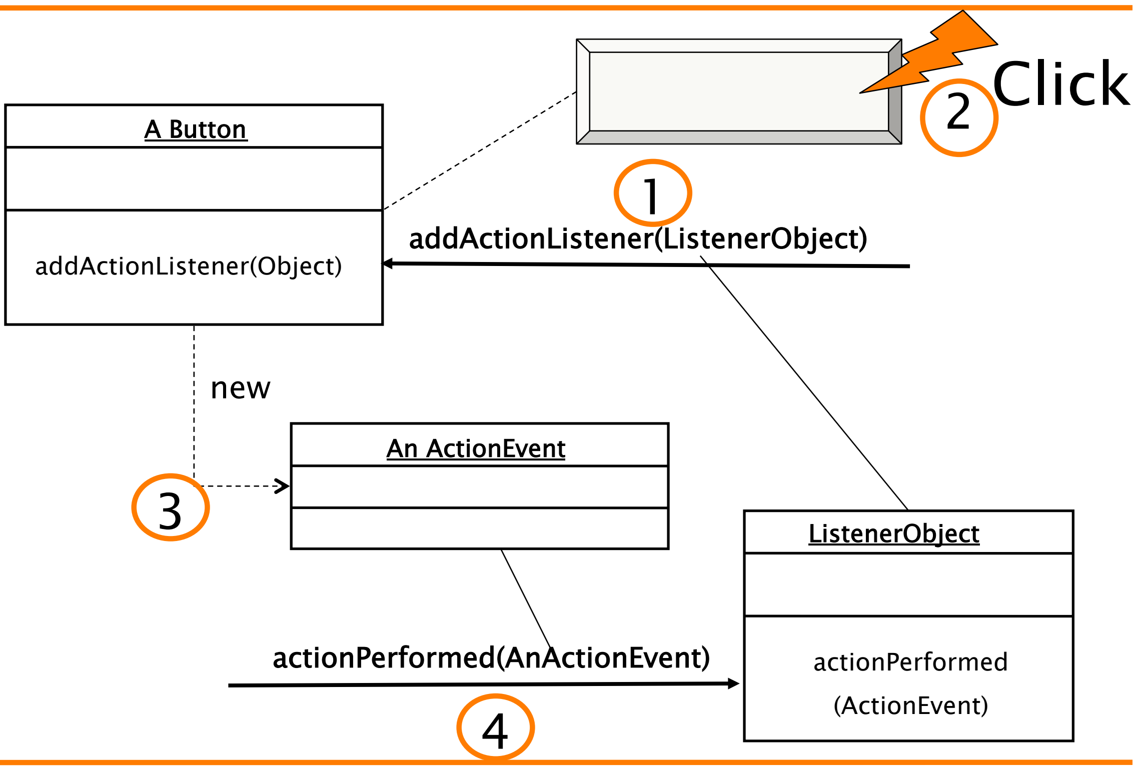




Events

- The events are represented by a hierarchy of classes. Each class is defined by the data representing that type of event.
- Some of the classes that are a set of events (MouseEvent) MAY CONTAIN AN ID that identifies the exact event type.

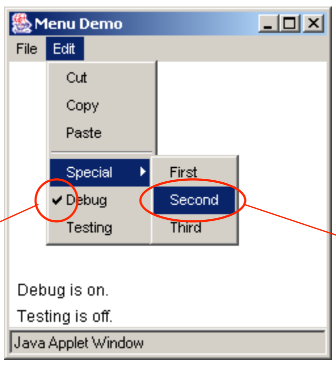
Example events


Click
2
A Button
addActionListener(Object)
1
addActionListener(ListenerObject)
new
3
An ActionEvent
ListenerObject
actionPerformed
(ActionEvent)
actionPerformed(AnActionEvent)
4

Events in Java: sources and types

Source	Event
Button	ACTION events → when the button is push
Box of choice	ELEMENT events → select/deselect
Menu	ACTION event → when you select a menu item; ELEMENT event → when a selectable menu item is activated
Window	WINDOW events → when the window is activated, maximized, minimized,...
...	

Difference between ‘selection – activation’



Debug is on.
Testing is off.

Activation → event of element

selection → event of action

Management of the events

- Events covered in Java :
  - Action event → click a button
  - Adjustment event → actions on scroll bars
  - Focus event → point the mouse on a text field
  - Item event → click on RadioButton, CheckBoxButton
  - Key event → keyboard input
  - Mouse event → click (not covered above)
  - Mouse-motion event → Simple displacement of the mouse
  - Window event → Enlarge, close a window

Managing events

- The principle underlying the events is quite similar to the exceptions :
  - A class declares which event is able to deal with (one or more) → implements one or more interfaces
  - It joins the listener set of the components that are source of events (**`JButton`**, **`JTextField`**, etc..) → **`aButton.addActionListener(controller)`**
    - Pay attention! You're implementing interfaces, so you must overwrite all methods of those interfaces!

How to manage the events in Java

```
class FrameWithEvents extends JFrame implements
InterfaceWithEvents {
     JComponent componentSourceofEvents =
                                    new JComponent();
     componentSourceOfEvents.addListener(this);
     void methodOfTheInterfaceWithEvents() {…}
     void anotehrMethodOfTheInterfaceWithEvents() {…}
}//end class
```

Listener Interfaces (1)

- **ActionListener** → Methods to override :
  - `void actionPerformed (ActionEvent evt)`
- **FocusListener** → Methods to overwrite :
  - `void focusGained (FocusEvent evt)`
  - `void focusLost (FocusEvent evt)`
- **ItemListener** → Methods to rewrite :
  - `void itemStateChanged (ItemEvent e)`

Listener Interfaces (2)

- `MouseListener` Methods to override:
  - `void mouseClicked (MouseEvent evt)`
  - `void mouseEntered (MouseEvent evt)`
  - `void mouseExited (MouseEvent evt)`
  - `void mousePressed (MouseEvent evt)`
  - `void mouseReleased (MouseEvent evt)`
- `MouseMotionListener` Methods to overrid:
  - `void mouseDragged (MouseEvent evt)`
  - `void mouseMoved (MouseEvent evt)`

Listener Interfaces (3)

- `KeyListener` Methods to override:
  - `void keyPressed (KeyEvent evt)`
  - `void keyReleased(KeyEvent evt)`
  - `void keyTyped(KeyEvent evt)`
- `WindowListener` (Methods to override:
  - `void windowActivated(WindowEvent evt)`
  - `void windowClosed (WindowEvent evt)`
  - `void windowClosing (WindowEvent evt)`
  - `void windowDeactivated (WindowEvent evt)`
  - `void windowDeiconified (WindowEvent evt)`
  - `void windowIconified (WindowEvent evt)`
  - `void windowOpened (WindowEvent evt)`

Add a listener

- Separate controller object

```
button.addActionListener( controller );
```

- Lambda expression relaying call

```
button.addActionListener( e -> doClick());
```

- The container itself (e.g. JFrame)

```
button.addActionListener( this );
```

Handle the event

- Identify the source of events
  - May be implicit in the anonym dispatcher

```
Object ob = evt.getSource();
if (ob == button ){
  // perform event handling
}
```

Note: == reference comparison

- Use event additional information
  - E.g. mouse position

Handle the event

- All methods accept an event as argument
  - The argument (KeyEvent, MouseEvent, etc.) provides methods to get information about the event:
- Examples
  - ActionListener
    - **`String getActionCommand()`**: returns a string identifying the component which generated the command
    - **`String paramString()`**: returns a string describing the event type (common to all event objects)

Event methods

- **`ItemEvent`**:
  - int **`getStateChange`**(): return SELECTED or DESELECTED on whether the RadioButton or the CheckBox is turned or less
- **`KeyEvent`**:
  - char **`getKeyChar`**(): returns the character typed
  - int **`getKeyCode`**(): returns the code of the key pressed o released

Homework

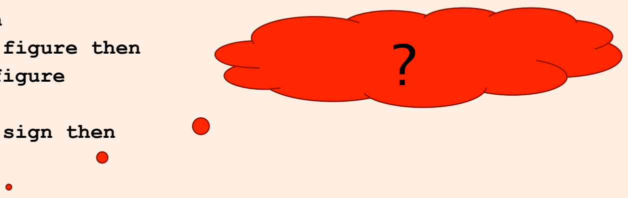
- Write a program Calcolator.java that realizes the functionality of a simple calculator. Requirements of the graphics interface:
  - 10 buttons with the figures from 0 to 9 prepared as in a traditional calculator;
  - Buttons relating to the operations of sum, subtraction, multiplication and division;
  - button “CE” To cancel the last number wrought ;
  - button “C” To clear any operation ;
  - button“=” To claim the result ;
  - button “.” To insert decimal places;
  - label to represent the display the calculator.

Observation

- Model the behavior of a "simple" Pocket calculator is not a simple activity : in order to make this exercise not too heavy from the point of view of the algorithms, you can simplify the following algorithm of calculation of arithmetic expressions introduced with the following hypotheses:
  - The expressions involve always and only 2 operandi ;
  - The user inserts always and only the first working operator, then the second working and the key "="; the result becomes the first working operator for the next operation
  - The only exception to the rule (2) is the case for buttons "C", "EC" AND "off" that can be pressed at any time.

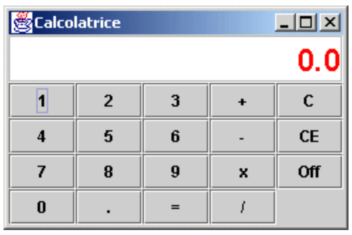
Algorithm of management (1)

```
state = NO_OPERATOR
buffer = 0
For each button pressed :
   if the state is NO_OPERATOR then
        If the button pressed is a figure then
             queues to buffer the figure
             view the buffer
        If the button pressed is a sign then
             operator1 = buffer
             operand = sign
             buffer = 0
             state = AN_OPERATOR
        if the button pressed is C or CE
             buffer = 0
             view the buffer
   otherwise, if the State is AN_OPERATOR then
        If the button pressed is a figure then
             queues to buffer the figure
             view the buffer
         If the button pressed is "=" then
             operator2 = buffer
             Calculate the term operatore1, a sign, operatore2 and visualize
        buffer = 0
             state = NO_OPERATOR
```



Algorithm of management

```
If the button pressed is C
        buffer = 0
         view the buffer
        state = NO_OPERATOR
If the button pressed is CE
        buffer = 0
         view the buffer
```



GUI TESTING

GUI testing

- To execute a test of a GUI there are two possible approaches:
  - Test from outside
  - Test from within

Test from outside

- Test from outside
  - Through the Operating System events are sent to the application emulating the user behavior
  - Pro: realistic approach
  - Cont: complex, OS dependent
  - There are specific tools that are able to capture operations performed by a user and to replay them later

Test from within

- Test from within
  - Specific methods can be invoked on graphical component to achieve a similar effect to that of a real usage (e.g. doClick() on a button)
  - Pro: simple, OS independent
  - Con: not realistic, not full interaction
  - Con: classes must be designed for testability
    - E.g. let selected attribute visible

GUI Test – Example

```
public void testGUI(){
  SimpleCassa gui = new SimpleCassa();
  gui.setVisible(true);
  gui.input.setText("P001");
  gui.pulsante.doClick();
  gui.input.setText("P002");
  gui.pulsante.doClick();
  gui.input.setText("P001");
  gui.pulsante.doClick();
  gui.input.setText("CLOSE");
  gui.pulsante.doClick();
  String output = gui.output.getText();
  assertTrue("wrong output",
            output.indexOf(″Sum: 7.5")>-1);
}
```

GRAPHICS

Direct drawing

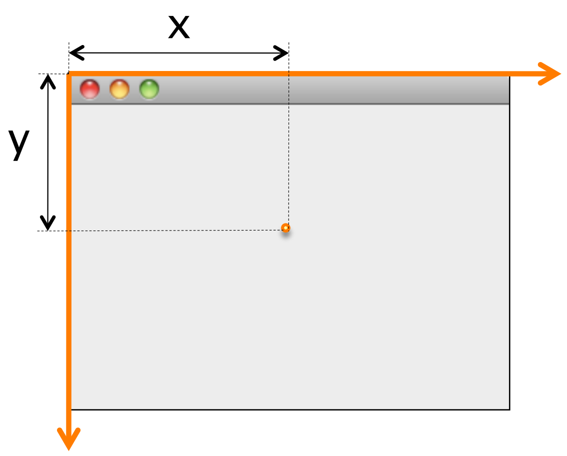
- Two elements are required to draw directly :
  - Method **`void paint(Graphics g)`**
    - Must be redefined in derived classes
    - Invoked by O.S.
  - Class **`Graphics`**
    - Provides methods to draw

Class Graphics

- Is the class that supports the capacity graphics applications, which draw lines, forms, characters and present images on screen, by means of a series of methods .
- The method **`paint()`** provides an object graphics acting on which draws on the screen.
  - It isn’t necessary to create an instance of the class graphics to draw on the screen

Class Graphics

- The coordinate system:
  - Origin in the top left corner
  - X increase moving to the right
  - Y increase moving downwards

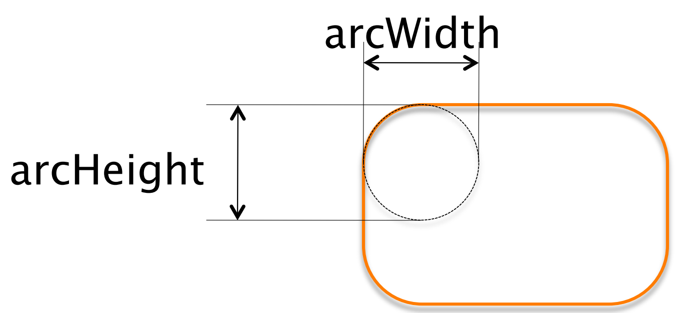


Graphics methods: lines

- **`drawLine(x1,y1,x2,y2)`**
  - Draw a line between two points
- **`drawRect(x,y,width,height)`**
  - Draw a rectangle (x,y) is upper left corner
  - Size is defined by width and height
- **`fillRect()`**
  - Same as above but rectangle is solid filled

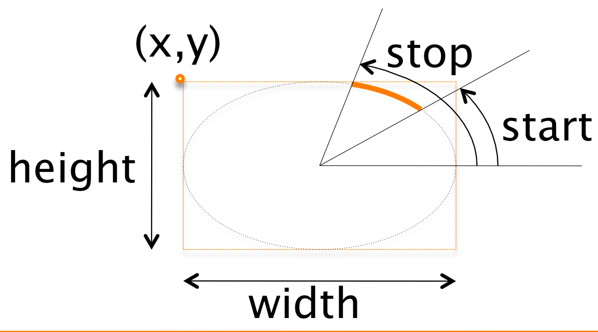
Graphics methods: rectangles

- **`drawRoundRect(x, y, width, height, arcWidth, arcHeight)`**
  - Draw a rectangle with rounded angles
- **`fillRoundRect(x, y, width, height, arcWidth, arcHeight)`**
  - Same as above but with solid filled shape



Graphics methods: ellipses

- **`drawOval(x,y,width,height)`**
  - Draw an ellipse inscribed in a rectangle located at (x,y) with the given size
- **`drawArc(x,y,width,height,start,stop)`**
  - Draw an arc of an ellipse starting at *start* degrees and stopping at *stop* degrees
- Also available:
  - **`fillOval()`**
  - **`fillArc()`**



Graphics methods: strings

- **`drawString(str,x,y)`**
  - Draw a string starting at point (x,y)
- **`drawChars(chars, offset, length, x, y)`**
  - Draw a char array starting at point (x,y)
  - Offset is the first char to draw
  - Length is the number of chars to draw

The string
(x,y)

Draw lines and squares

- To draw a line

```
g.drawLine(25, 25, 75, 75);
```

- To Draw a rectangle, specifying the coordinated point in the top left, width and length:

```
g.drawRect(20, 20, 60, 60);
g.fillRect(120, 20, 60, 60);
```

- To Draw a rectangle, specifying the coordinated point in the top left, width and length:

```
g.drawRoundRect(20,20, 60,60, 10,10);
g.fillRoundRect(120,20, 60,60, 20,20);
```

Draw polygons

- A polygon requires a set of points defined as two x and y arrays:

```
int x[ ] = {39,94,97,142,53,58, 26};
int y[ ] = {33,74,36,70,108,80, 106};
int points = x.length;
g.drawPolygon(x,y,points);
```

- ..or as instances of the class polygon:

```
Polygon poly = new Polygon(x,y,points);
g.fillPolygon(poly);
```

- The polygon is closed automatically

  `drawPolyline()` allows to have open polygons.

Draw ellipses and arcs

- To draw circles or ellipses using the oval .

```
g.drawOval(20, 20, 60, 60);
g.fillOval(120, 20, 100, 60);
```

- Arcs are defined as pieces of ellipses with the method drawArc()
  - An ellipsis must be defined plus the starting and ending angles. Which are defined counterclockwise (90 vertical axis).

```
g.drawArc(20, 20, 60, 60, 90, 180);
g.fillArc(120, 20, 60, 60, 90, 180);
```

Draw strings

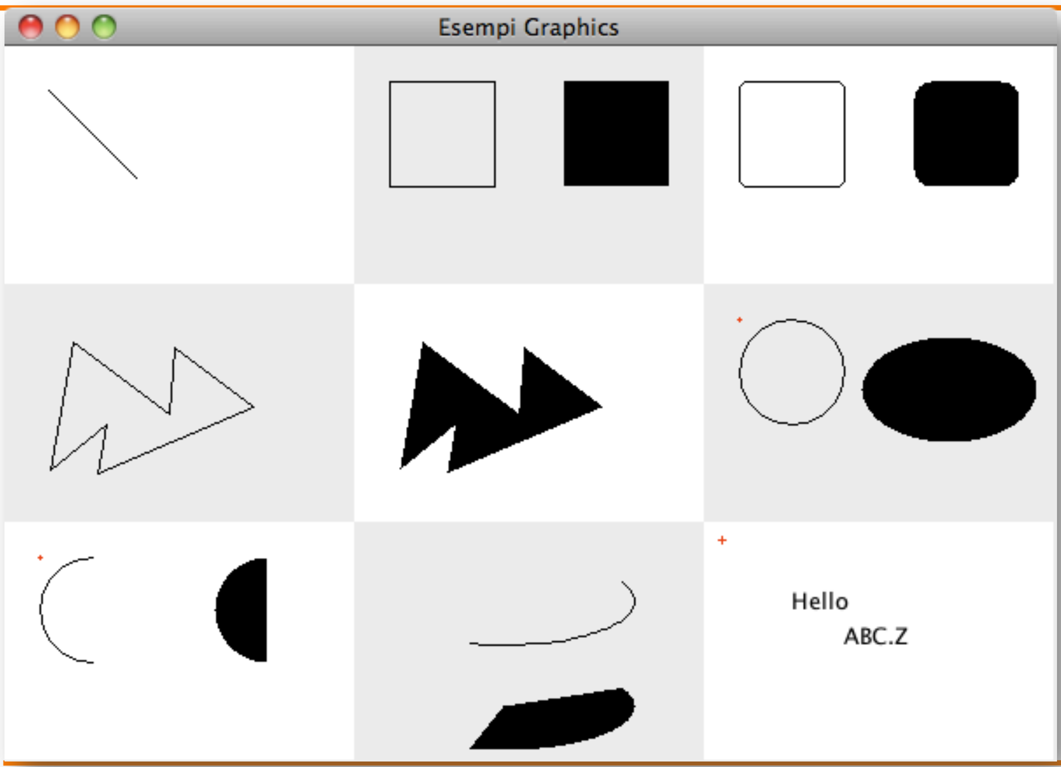
- To draw strings use:

```
g.drawString("Hello", 50, 50);
```

- ..or draw an array of chars:

```
char[] chars = new char[]
{'A','B','C','.','Z'};
g.drawChars(chars,0,chars.length,80,70);
```

Examples



Repaint

- Method **`paint()`** is invoked by OS when needed
  - E.g. window resize, de-iconify
- Method **`repaint()`** signals that window contents must be updated
  - Later OS will invoke paint()
- This method is essential to update the view when something is changed

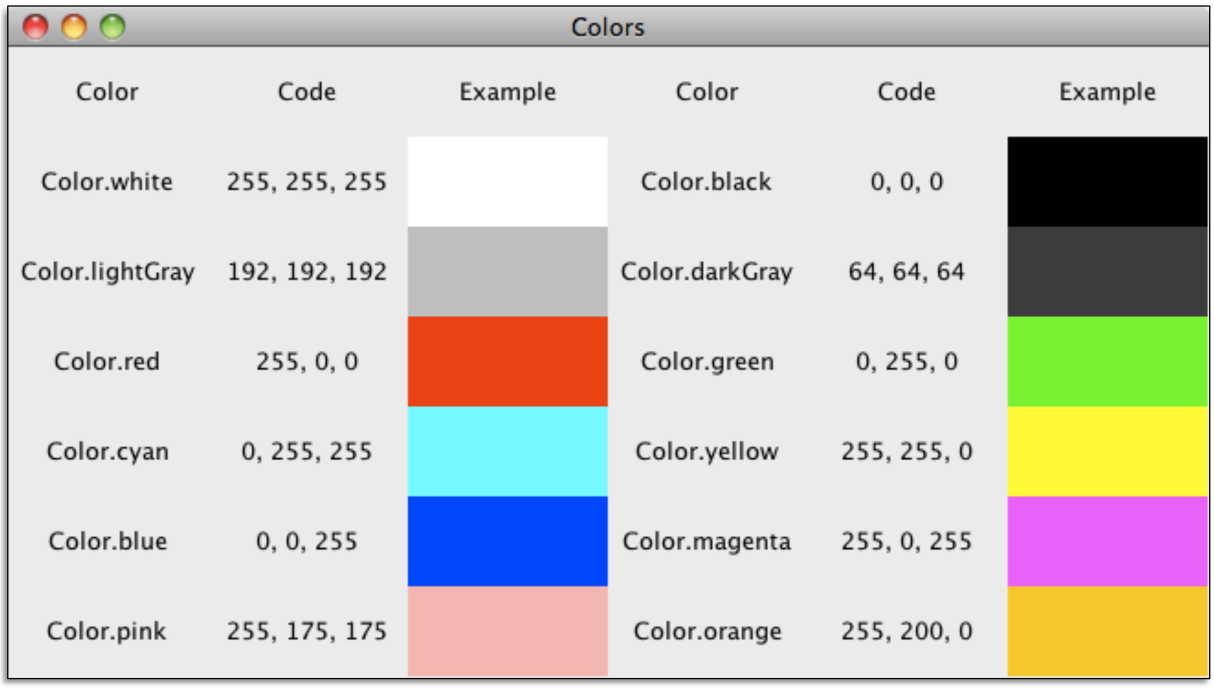
Color management

- The management of colors is performed through class Color.
  - Colors are encoded on 24 bit; each color and consists of a combination of red, green and blue .
  - Each component is represented with a whole number between 0 and 255.
- There are class constants defined for the main colors.

Color management

- For windows (JFrame):
  - **`setBackground(Color c)`**
    - Sets the window internal background
  - **`setForeground(Color c)`**
    - Sets the components foreground color
- For Graphics:
  - **`setColor(Color c)`**
    - Sets the color for all the successive drawing operations

Color management



Color	Code	Example	Color	Code	Example
Color.white	255, 255, 255	⬜	Color.black	0, 0, 0	⬛
Color.lightGray	192, 192, 192	⬜	Color.darkGray	64, 64, 64	⬛
Color.red	255, 0, 0	🟥	Color.green	0, 255, 0	🟩
Color.cyan	0, 255, 255	🟦	Color.yellow	255, 255, 0	🟨
Color.blue	0, 0, 255	🟦	Color.magenta	255, 0, 255	🟪
Color.pink	255, 175, 175	🟫	Color.orange	255, 200, 0	🟧

Font management

- Fonts are represented by class Font
- Constructor

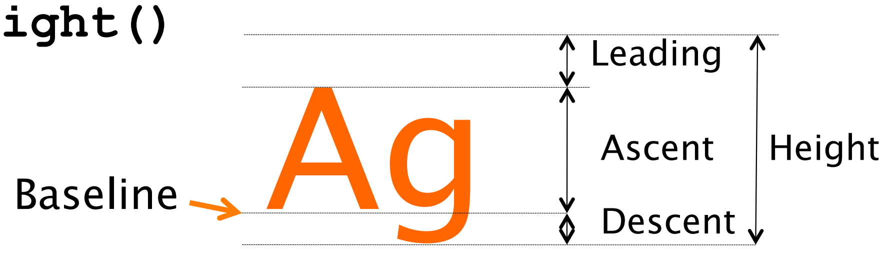
  `Font(String face, int attrs, int size)`
- Parameters
  - Face is the name of the font e.g. “TimesRoman”
  - Attrs represent attributes e.g. Font.BOLD
  - Size is expressed in points

Font management

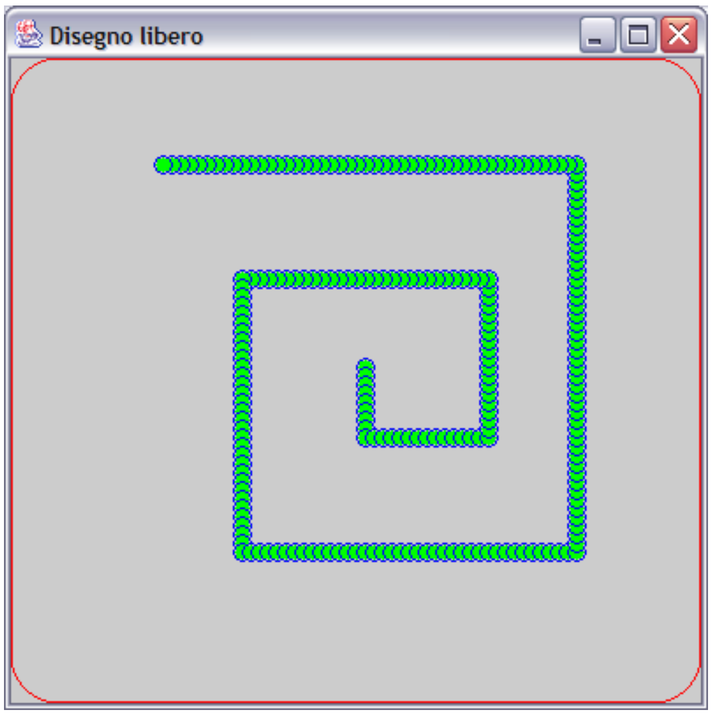
- To get information about a font:
  - **`getFont()`**: returns the current font
  - **`getName()`**: returns font name
  - **`getSize()`**: returns the font size
  - **`getStyle()`**:, Return the style of font
  - **`isPlain()`**, **`isBold()`** , **`isItalic()`**: return the font modifications
- For more information more specific on the individual font use the class **`FontMetrics`**.

FontMetrics

- Main methods are:
  - **`stringWidth()`**: width in pixels of a given string
  - **`charWidth()`**: amplitude of a char
  - **`getAscent()`**
  - **`getDescent()`**
  - **`getLeading()`**
  - **`getHeight()`**



Example



Example

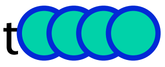
```
public class Drawing extends JFrame{
  int x;
  int y;
  public void paint(Graphics g){
   Rectangle b = getBounds();
   g.setColor(Color.RED);
   g.drawRoundRect(4,30,
      b.width-9,b.height-35,50,50);
   g.setColor(Color.BLUE);
   g.drawOval(x,y,10,10);
   g.setColor(Color.GREEN);
   g.fillOval(x+1,y+1,9,9);
  }
}
```

g covers the full window area, including borders

Events

```
public class Drawing implements KeyListener{
  public void keyPressed(KeyEvent e)  {
   if(e.getKeyCode()==KeyEvent.VK_DOWN){
      moveXY(0,5);
   }
   // …
  }
  void moveXY(int deltaX, int deltaY){
   x+=deltaX;
   y+=deltaY;
   this.repaint();
  }
}
```

Considerations

- The repaint operation does not erase the window
  - Therefore we have the trail effect
- We need to explicitly erase the content of the window:

```
Rectangle bounds = getBounds();
g.clearRect(0,0,bds.width,bounds.height);
```

Advices

- Define a method paint on an empty (e.g. without borders) compoment
- DO NOT override method **`paint()`** on a frame containing components
- Usually a **`JPanel`** is a good candidate to override method **`paint()`**

Summary

- GUI can be build using the MVC pattern:
  - Model: hosts the data
  - View: show the data
  - Controller: manages the interaction
- The view can be build using different libraries:
  - AWT
  - Swing
  - JavaFX

Summary

- In Swing the main elements are
  - JFrame that represent the view container
  - JComponent is the root class of all controls:
    - JButton
    - JLabel
    - JTextField
    - JPanel
    - …

Summary

- The interaction takes place when an event is generated and managed by the appropriate listener
  - A listener must be registered for a component and a specific event category
  - When the event is generated the appropriate method of the listener is called back
  - The method can handle the event as required