DM503
Programming B

Peter Schneider-Kamp

petersk@imada.sdu.dk

http://imada.sdu.dk/~petersk/DM503/

GRAPHICAL USER INTERFACES

HelloWorld Reloaded

- Java standard GUI package is Swing
- from popup message to professional user interface
- Example:

```
import javax.swing.*;
public class HelloWorldSimple {
    public static void main(String[] args) {
        JOptionPane.showMessageDialog(null, "Hello World!");
    }
}
```

- more challenging to do anything more complicated
- multi-threaded event-driven model-based UI design :-o

Dialogs

- user dialogs are created using JDialog class
- basically like JFrame (next slide), but with a parent window
- often used via static JOptionPane methods
- Example:

```
Object[] options = {1, 2, 3, 4, 5, 10, 23, 42};
Object result = JOptionPane.showInputDialog(null,
    "Select number", "Input",
    JOptionPane.INFORMATION_MESSAGE, null,
    options, options[0]);
int selectedInt = (Integer) result;
```

Creating a Window

- windows are represented by objects of class JFrame
- constructor gets title displayed at top of window
- Example:

```
JFrame window = new JFrame("My first window!");

window.setSize(400, 250);      // set size of window to 700x400
window.setLocation(50, 50);   // top-left corner at (50, 50)

// exit program when window is closed
window.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

window.setVisible(true);       // show window on the screen
```

Creating Content

- content is placed in objects of class JPanel
- on these we can either
  - draw directly on it using the paintComponent method
  - add ready-made components using the add method
- every window has a JPanel as its main "content pane"
- Example 1 (draw directly):

```
public class MyPanel extends JPanel {
    public void paintComponent(Graphics g) {
        super.paintComponent(g);
        g.drawString("My first panel!", 100, 100);
    }
}
```

Creating Content

- content is placed in objects of class JPanel
- on these we can either
  - draw directly on it using the paintComponent method
  - add ready-made components using the add method
- every window has a JPanel as its main "content pane"
- Example 2 (add a button):

```
JButton button = new JButton("My first button!");
button.addActionListener(new ButtonHandler());
JPanel panel = new JPanel();
panel.add(button);
window.setContentPane(panel);
window.pack();
```

Listeners and Events

- events = changes in the user interface
- mouse movement, key pressed, button clicked, …

- listeners = objects that respond to events
- Example (ActionListener for button from previous slide):

```
import java.awt.*;
import java.awt.event.*;
public class ButtonHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
        System.exit(0);
    }
}
```

Mouse Events

- interface MouseListener for mouse events
- needs to be added using addMouseListener methods
- often component class implementing the interface itself
- Example (panel that changes color during click):

```
public class Clicky extends JPanel implements MouseListener {
    public Clicky() {  this.addMouseListener(this);  }
    public void mousePressed(MouseEvent event) {
        this.setBackground(Color.RED);
    }
    public void mouseReleased(MouseEvent evt) {
        this.setBackground(Color.GRAY);
    }  …  }
```

Colors

- colors are represented by objects of class Color
- define by RGB values or use pre-defined constants
- Example:

```
import java.awt.*;
…
JPanel panel = new JPanel(new BorderLayout());
JPanel panelA = new JPanel();
panelA.setBackground(new Color(192, 64,128)); // strange color
JPanel panelB = new JPanel();
panelB.setBackground(Color.RED));
panel.add(panelA, BorderLayout.NORTH);
panel.add(panelB, BorderLayout.SOUTH);
```

Labels

- simple component to display strings or images
- labels are objects of class JLabel
- text, colors, fonts etc. can be changed during runtime
- Example:

```
JLabel label = new JLabel("My first label!", JLabel.CENTER);
…
label.setText("something more interesting");
label.setForeground(Color.BLUE);
label.setBackground(Color.YELLOW);
label.setOpaque(true);                    // background filled
label.setFont(new Font("Serif", Font.ITALIC, 15));
```

Fonts

- fonts represented by objects of class Font
- constructor takes name, style, and point size
- see Java API documentation for more examples
- Example:

```
import java.awt.*;
…
Font font = new Font("Arial", Font.BOLD, 42);
JButton button = new JButton("Click me!");
button.setFont(font);
…
```

Borders

- borders are represented by objects of class Border
- borders can be added to any component
- typically created using static methods in BorderFactory
- Example:

```
JPanel panel = new JPanel(new GridLayout(3,3));
for (int i = 0; i < 9; i++) {
    JPanel subPanel = new JPanel();
    subPanel.setBorder(BorderFactory.createLineBorder(
        Color.BLACK));
    panel.add(subPanel);
}
```

Panel Layout

- layout = spatial organization of components
- components can be either
  - organized by absolute coordinates
  - organized by an object of class LayoutManager
- Example 1 (layout with BorderLayout):

```
JPanel panel = new JPanel(new BorderLayout());
panel.add(new JButton("North"), BorderLayout.NORTH);
panel.add(new JButton("Center"), BorderLayout.CENTER);
panel.add(new JButton("West"), BorderLayout.WEST);
panel.add(new JButton("South"), BorderLayout.SOUTH);
panel.add(new JButton("East"), BorderLayout.EAST);
```

Panel Layout

- layout = spatial organization of components
- components can be either
  - organized by absolute coordinates
  - organized by an object of class LayoutManager
- Example 2 (layout with GridLayout):

```
JPanel panel = new JPanel(new GridLayout(2,3));
panel.add(new JButton("North"));
panel.add(new JButton("Center"));
panel.add(new JButton("West"));
panel.add(new JButton("South"));
panel.add(new JButton("East"));
```

Basic Components

- buttons represented by objects of class JButton
- Example (disabled button with text label):

```
JButton button = new JButton("Big, bad, and ugly!");
button.addActionListener(new MyButtonHandler());
button.setEnabled(false);
```

- check boxes represented by objects of class JCheckBox
- Example (initially selected two-state check box):

```
JCheckBox checkBox = new JCheckBox("more money!", true);
…
boolean wantsMore = checkBox.isSelected();
```

Basic Components

- selectable options represented by objects of class JComboBox
- Example (select from a list of numbers):

```
Object[] options = {1, 2, 3, 4, 5, 10, 23, 42};
JComboBox optionBox = new JComboBox(options);
optionBox.setSelected(6);
optionBox.addActionListener(new MySelectionHandler());
…
int selectedInt = (Integer) optionBox.getSelectedItem();
```

Basic Components

- selection on a range of values by objects of class JSlider
- Example (select percentage from 0 to 100, initally 50):

```
JSlider percent = new JSlider(0, 100, 50);
percent.setMajorTickSpacing(25);
percent.setMinorTickSpacing(5);
percent.setPaintTicks(true);
percent.setPaintLabels(true);
percent.addChangeListener(new MyChangeHandler());
```

Text Components

- text fields represented by objects of class JTextField
- Example (text field for email input):

```
JTextField email = new JTextField();
…
String userEmail = checkRFC5322(email.getText());
```

- text areas represented by objects of class JTextArea
- Example (full-window scrollable editable text entry area):

```
JTextArea entryArea = new JTextArea(5, 20);
textArea.setEditable(true);
JScrollPane scrollPane = new JScrollPane(textArea);
window.getContentPane().add(scrollPane);
```

Menus

- menus represented by JMenuBar, JMenu, and JMenuItem
- Example (menu bar with a single file menu with three items):

```
JMenu file = new JMenu("File");        // create drop down menu
JMenuItem open = new JMenuItem("Open");
file.add(open);          open.addActionListener(this);
JMenuItem save = new JMenuItem("Save");
file.add(save);          save.addActionListener(this);
JMenuItem saveas = new JMenuItem("Save as ...");
file.add(saveas);        saveas.addActionListener(this);
JMenuBar menuBar = new JMenuBar();       // menu bar
menuBar.add(file);
```

Menus

- menus represented by JMenuBar, JMenu, and JMenuItem
- Example (menu bar with a single file menu with three items):

```
public class MyMenu implements ActionListener {
    public MyMenu() {
        …          // see previous slide
    }
    public void actionPerformed(ActionEvent e) {
        …          // check which menu item was clicked and react
    }
}
```

ABSTRACT DATATYPES

Abstract Datatype (ADT)

- abstract datatype = data + operations on the data
- **Idea:** encapsulate data + operations with uniform interface

- operations of a datatype
  - at least one constructor
  - modifiers / setters
  - readers / getters
  - computations

- ADTs typically specified by interfaces in Java

Abstract Datatype (ADT)

- abstract datatype = data + operations on the data
- when specifying an ADT, we describe
  - the data and its *logical* organization
  - which operations we want to be able to perform
  - what the results of the operations should be
- we do NOT describe
  - where and how the data is stored
  - how the operations are performed
- ADTs are independent of the implementation (& language)
- one ADT can have many different implementations!

Examples for ADTs

- Numbers: (integer, rational or real)
  - addition, subtraction, multiplication, division, …
- Collections: (collections of elements)
  - List: (ordered collections of elements)
    - Stack (insert & remove elements at one end)
    - Queue (insert at one end, remove at the other)
  - Set: (unordered collection without duplicates)
    - SortedSet (ordered collection without duplicates)
  - Map: (mapping from keys to values)

Developing ADTs

- three steps (like in programming!)

1. specification of an ADT by mathematical means
   - focus on WHAT we want
2. design (still independent of implementation & language)
   - which data structures to use
   - which algorithms to use
   - focus on efficiency of representation and algorithms
   - different data structures give different efficiency for operations
3. implementation (language dependent)
   - select "right" programming language!
   - implement design in that programming language

Specification of an ADT

- mathematically precise!

- data is represented by mathematical objects
- Example: real numbers $\Re$

- operations are mathematical functions
  - explicit specifications
  - Example: $f(x) = x^2$

  - indirect specifications
  - Example: $sqrt : x \in \Re^{\geq 0} \mapsto y \in \Re^{\geq 0}$

    $x = y^2 \wedge y \geq 0$

Integer ADT

- specification:
  - data: all $n \in \mathbb{N}$
  - operations: addition +, subtraction -, negation -, multiplication *, division /
- Design 1: use primitive data type int
  use primitive operations
- Implementation 1: nothing to implement when using Java
- Design 2: use array of bytes to store bit
  provide all relevant operations
- Implementation 2: see class java.math.BigInteger

Integer ADT

- specifying by mathematics often cumbersome
- alternatively use interfaces to specify operations
- alternative specification:
  - data: all $n \in \mathrm{N}$
  - operations:

```
public interface MyInteger {
    public MyInteger add(MyInteger val);      // addition
    public MyInteger sub(MyInteger val);      // subtraction
    public MyInteger neg();                   // negation
    public MyInteger mul(MyInteger val);      // multplication
    public MyInteger div(MyInteger val);      // division
}
```

ABSTRACT DATATYPE FOR LISTS

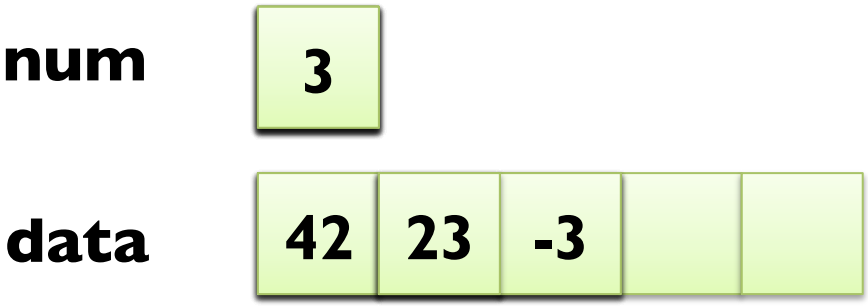
List ADT: Specification

- data are all integers, here represented as primitive int
- operations are defined by the following interface

```
public interface ListOfInt {
    public int get(int i);                  // get i-th integer (0-based)
    public void set(int i, int elem);       // set i-th element
    public int size();                      // return length of list
    public void add(int elem);              // add element at end
    public void add(int i, int elem);       // insert element at pos. i
    public void remove(int i);              // remove i-th element
}
```

Partially Full Arrays

- arrays are fixed-length
- lists are variable-length
- **Idea:**
  - use an array of (fixed) length
  - track number of elements in variable
- **Example:** add(23) | add(42) | add(-3) | remove(0) | add(1, 23)



List ADT: Design & Implementation 1

- Design 1: partially full arrays of int
- Implementation 1:

```
public class PartialArrayListOfInt implements ListOfInt {
    private int limit;              // maximal number of elements
    private int[] data;             // elements of the list
    private int num = 0;            // current number of elements
    public PartialArrayListOfInt(int limit) {
        this.limit = limit;
        this.data = new int[limit];
    }
    …
}
```

List ADT: Implementation 1

- Implementation 1 (continued):

```
public class PartialArrayListOfInt implements ListOfInt {   …
    private int[] data;
    private int num = 0;   …
    public int get(int i) {
        if (i < 0 || i >= num) {
            throw new IndexOutOfBoundsException();
        }
        return this.data[i];
    }
    …
}
```

List ADT: Implementation 1

- Implementation 1 (continued):

```
public class PartialArrayListOfInt implements ListOfInt {   …
    private int[] data;
    private int num = 0;   …
    public void set(int i, int elem) {
        if (i < 0 || i >= num) {
            throw new IndexOutOfBoundsException();
        }
        this.data[i] = elem;
    }
    …
}
```

List ADT: Implementation 1

- Implementation 1 (continued):

```
public class PartialArrayListOfInt implements ListOfInt {   …
    private int[] data;
    private int num = 0;   …
    public int size() {
        return this.num;
    }
    public void add(int elem) {
        this.add(this.num, elem);          // insert at end
    }
    …
}
```

List ADT: Implementation 1

- Implementation 1 (continued):

```
public class PartialArrayListOfInt implements ListOfInt {   …
    public void add(int i, int elem) {
        if (i < 0 || i > num) {  throw new Index…Exception();  }
        if (num >= limit) {  throw new RuntimeException("full!");  }
        for (int j = num-1; j >= i; j--) {
            this.data[j+1] = this.data[j];   // move elements right
        }
        this.data[i] = elem;                 // insert new element
        num++;                               // one element more!
    }
    …   }
```

List ADT: Implementation 1

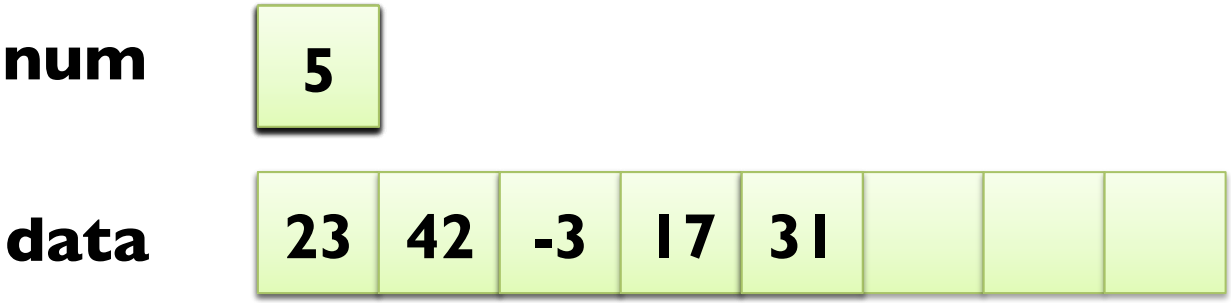
- Implementation 1 (continued):

```
public class PartialArrayListOfInt implements ListOfInt {   …
    public void remove(int i) {
        if (i < 0 || i >= num) {  throw new Index…Exception();  }
        for (int j = i; j+1 < num; j++) {
            this.data[j] = this.data[j+1];   // move elements left
        }
        num--;                                  // one element less!
    }
    // DONE!
}
```

Dynamic Arrays

- arrays are fixed-length
- lists are variable-length
- **Idea:**
  - use an array of (fixed) length & track number of elements
  - extend array as needed by add method

- **Example:**



List ADT: Design & Implementation 2

- Design 2: dynamic arrays of int
- Implementation 2:

```
public class DynamicArrayListOfInt implements ListOfInt {
    private int limit;              // current maximum number
    private int[] data;             // elements of the list
    private int num = 0;            // current number of elements
    public DynamicArrayListOfInt(int limit) {
        this.limit = limit;
        this.data = new int[limit];
    }
    …
}
```

List ADT: Implementation 2

- Implementation 2 (continued):

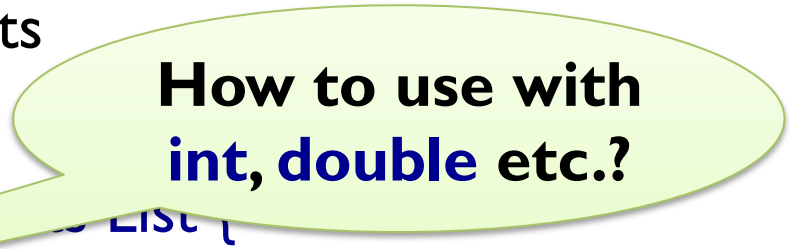
```
public void add(int i, int elem) {
    if (i < 0 || i > num) {  throw new Index…Exception();  }
    if (num >= limit) {          // array is full
        int[] newData = new int[2*this.limit];
        for (int j = 0; j < limit; j++) {
            newData[j] = data[j];
        }
        this.data = newData;
        this.limit *= 2;
    }
    …   }      // rest of add method
```

List ADT: Design 2 Revisited

- Design 2 (revisited): symmetric dynamic arrays of int
  - keep startIndex and endIndex of used indices
  - start with startIndex = endIndex = limit / 2
  - i.e., limit / 2 free positions at the beginning
  - i.e., limit / 2 free positions at the end
  - extend array at the beginning when startIndex < 0 needed
  - extend array at the end when endIndex > limit needed
  - shrink array in remove, when (endIndex – startIndex) < limit / 4

List ADT: Design 3

- goal is to use list for arbitrary data types
- Design 3: dynamic arrays of objects
- Implementation 3:




```
public class DynamicArrayList implements List {
    private int limit;              // current maximum number
    private Object[] data;          // elements of the list
    private int num = 0;            // current number of elements
    public DynamicArrayListOfInt(int limit) {
        this.limit = limit;
        this.data = new Object[limit];
    }  …
}
```

Boxing and Unboxing

- primitive types like int, double, … are not objects!

- Java provides wrapper classes Integer, Double, …
- Example:
```
Integer myInteger = new Integer(13);
int myInt = myInteger.intValue();
```

- transparent due to *automatic boxing* and *unboxing*
- Example:
```
Integer myInteger = 13;
int myInt = myInteger;
```

- useful when e.g. storing int values in a Object[]

List ADT: ArrayList

- Java provides pre-defined symmetric dynamic array list implementation in class java.util.ArrayList
- Example:

```
ArrayList myList = new ArrayList(10);          // initial limit 10
for (int i = 0;  i < 100;  i++) {
    myList.add(i*i);                  // list of squares of 0 … 99
}
System.out.println(myList);
for (int i = 99;  i >= 0;  i--) {
    int n = (Integer) myList.get(i);       // get returns Object
    myList.set(i, n*n);                    // now to the power of 4!
}
```

Generic Types

- type casts for accessing elements are unsafe!
- solution is to use *generic types*
- instead of using an array of objects, use array of some type E
- Example:

```
public class MyArrayList<E> implements List<E> {
    …
    private E[] data;
    …
    public E get(int i) {
        return this.data[i];
    }
}
```

Finding in Lists

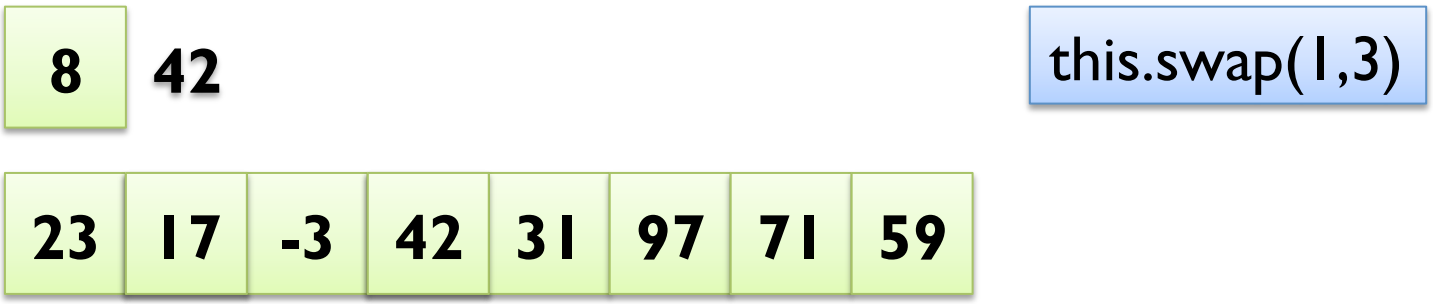
- finding typical example for another List ADT operation
- specified by the following method signature:

```
public int indexOf(E elem) {
    for (int i = 0; i < this.size(); i++) {
        E cand = this.get(i);
        if (elem == null ? cand == null : elem.equals(cand)) {
            return i;        // found an equal element
        }
    }
    return -1;               // did not find any match
}
```

Sorting Lists

- sorting is another important List ADT operation
- many different approaches to sorting exist
- more on this: **DM507 Algorithms and Data Structures**
- Example (Selection Sort):

```
private void swap(int i1, i2) {
    E temp = this.get(i1);
    this.set(i1, this.get(i2));
    this.set(i2, temp);
}
```



Sorting Lists

- sorting is another important List ADT operation
- many different approaches to sorting exist
- more about this in DM507 Algorithms and Data Structures
- Example (Selection Sort):

```
public void selectionSort() {
    for (int firstPos = 0;  firstPos < this.size()-1;  firstPos++) {
        int minPos = this.size()-1;  // assume last element is smallest
        for (int i = firstPos; i < this.size()-1; i++) {
            if (this.get(i) < this.get(minPos)) {  minPos = i;  }
        }
        this.swap(minPos, firstPos);
}   }
```

Sorting Lists

```
public void selectionSort() {
    for (int firstPos = 0;  firstPos < this.size()-1;  firstPos++) {
        int minPos = this.size()-1;  // assume last element is smallest
        for (int i = firstPos; i < this.size()-1; i++) {
            if (this.get(i) < this.get(minPos)) {  minPos = i;  }
        }
        this.swap(minPos, firstPos);
    }
}
```