Serialization

Sending Complex Java Data Structures to Files or Over the Network

Originals of Slides and Source Code for Examples:
http://courses.coreservlets.com/Course-Materials/java.html

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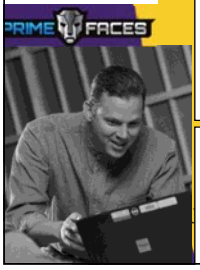


Agenda

- Idea
- Requirements
- Steps for sending data
- Steps for receiving data
- Example: saving GUI in file
- Example: sending GUI across network

Overview

Idea of Serialization

- **Java lets you send arbitrarily complex data structures with a single command**
  - writeObject from ObjectOutputStream
    - Can write to file, socket, process, etc.
  - Almost any data type: ArrayList, array, Frame, Panel, custom classes, etc. Arbitrarily nested.
    - Custom classes must implement Serializable
- **Java lets you read complex data structures in a single command**
  - readObject from ObjectInputStream
    - Can read from file, socket, process, etc.
  - Receiver must have class files for custom classes
  - Receiver must be on same major version of Java

Requirements

- **Top-level data structure and all internal components must implement Serializable**
  - Most builtin classes already do
    - ArrayList, HashMap, array, String, Frame/JFrame, Panel/JPanel, Button/JButton, etc.
    - Primitives are OK inside data structures.
      - No need for wrapper classes.
  - Making your own classes serializable is simple
    - Just say “implements Serializable” (no methods!)
    - Bottom-most non-Serializable class must have a zero-argument constructor. (I.e., parent of first Serializable class. Object is OK.)
- **Both ends must use same major version of Java**
  - I.e., sender cannot use 1.6 and receiver use 1.7 or vice versa
- **Both ends must have same version of class files**
  - E.g., if you add a method to your class, old serialized data is no longer valid

Sending Data

Sending Data: Summary

- **Wrap an ObjectOutputStream around any regular OutputStream**
  - To file

```
FileOutputStream fileOut =
  new FileOutputStream("SomeFile.ser");
ObjectOutputStream out =
  new ObjectOutputStream(fileOut);
```

  - To socket

```
OutputStream socketOut =
  someSocket.getOutputStream();
ObjectOutputStream out =
  new ObjectOutputStream(socketOut);
```

- **Send top-level data structure**

```
out.writeObject(theData);
out.close();
```

Sending Data to File: Details (Example for Array of Shapes)

```
try(FileOutputStream fileOut =
      new FileOutputStream("shapes.ser");
    ObjectOutputStream out =
      new ObjectOutputStream(fileOut)) {
  Shape[] shapes = { new Circle(...),
                     new Rectangle(...),
                     ...};
  out.writeObject(shapes);
} catch(IOException ioe) {
  System.out.println("Error sending data" + ioe);
}
```


Sending Data to Socket : Details (Example for Array of Shapes)

```
try {
  Shape[] shapes = { new Circle(...),
                     new Rectangle(...),
                     ...};
  Socket socket = new Socket("host", port);
  // Or Socket socket = serverSock.accept();
  OutputStream socketOut =
    socket.getOutputStream();
  ObjectOutputStream out =
    new ObjectOutputStream(socketOut);
  out.writeObject(shapes);
  out.close();
} catch(IOException ioe) {
  System.out.println("Error sending data" + ioe);
}
```

Receiving Data

Receiving Data: Summary

- **Wrap an ObjectInputStream around any regular InputStream**
  - From file

```
FileInputStream fileIn =
  new FileInputStream(new File("SomeFile.ser"));
ObjectInputStream in =
  new ObjectInputStream(fileIn);
```

  - From socket

```
InputStream socketIn =
  someSocket.getInputStream();
ObjectInputStream in =
  new ObjectInputStream(socketIn);
```

- **Read top-level data structure**

```
SomeType var = (SomeType)in.readObject();
```

Reading Data from File: Details (Example for Array of Shapes)

```
try(FileInputStream fileIn =
     new FileInputStream(new File("shapes.ser"));
    ObjectInputStream in =
      new ObjectInputStream(fileIn)) {
  Shape[] shapes = (Shape[])in.readObject();
} catch(IOException ioe) {
  System.out.println("Error reading file: "
                     + ioe);
} catch(ClassNotFoundException cnfe) {
  System.out.println("No such class: " + cnfe);
}
```


Reading Data from Socket: Details (Example for Array of Shapes)

```
try {
  Socket socket = new Socket("host",port);
  // Or Socket socket = serverSock.accept();
  InputStream socketIn = socket.getInputStream();
  ObjectInputStream in
    new ObjectInputStream(socketIn);
  Shape[] shapes = (Shape[])in.readObject();
} catch(IOException ioe) {
    System.out.println("Error reading socket: "
                       + ioe);
} catch(ClassNotFoundException cnfe) {
    System.out.println("No such class: " + cnfe);
}
```

Example: Sending Entire Window to File or Network

Example: SaveableFrame

- **Data:**
  - Main Frame (Frame already Serializable)
  - Frame has internal fields (ints) representing width, height, colors, layout manager, and location on screen
  - Two subpanels (Panel already Serializable)
  - Bottom panel has 2 buttons (Button already Serializable)
  - Top panel has:
    - Custom mouse listener that explicitly implements Serializable
    - BetterCircle objects that are created when user presses mouse. (Extends Component, which already implements Serializable)
- **Sending to/from file**
  - Clicking "Save" sends state of Frame to file.
  - If file exists when program starts, old state taken from file
- **Sending to/from network**
  - Server created that sends state of Frame to any client
  - Client created that connects to server and gets copy of Frame

SaveableFrame (Custom Class)

```
import java.awt.*;
import java.awt.event.*;
import java.io.*;

public class CirclePanel extends Panel {
  private class ClickAdapter extends MouseAdapter
                             implements Serializable {
    public void mousePressed(MouseEvent event) {
      BetterCircle circle =
        new BetterCircle(Color.BLACK, 25);
      add(circle);
      circle.setCenter(event.getX(), event.getY());
    }
  }

  public CirclePanel() {
    setLayout(null);
    addMouseListener(new ClickAdapter());
  }
}
```

Already Serializable

Not already Serializable

SaveableFrame (Base Code to Send Frame)

- **SaveableFrame.java**

```
public void sendFrame(OutputStream rawOut) {
  try(ObjectOutputStream out =
        new ObjectOutputStream(rawOut)) {
    out.writeObject(this);
  } catch(IOException ioe) {
    System.out.println("Error saving frame: " + ioe);
  }
}
```

SaveableFrame (Code to Send Frame to File)

- **SaveableFrame.java**

```
@Override
public void actionPerformed(ActionEvent event) {
  if (event.getSource() == clearButton) {
    circlePanel.removeAll();
    circlePanel.repaint();
  } else if (event.getSource() == saveButton) {
    try(FileOutputStream fileOut =
          new FileOutputStream("SavedFrame.ser")) {
      sendFrame(fileOut);
    } catch(IOException ioe) {
      System.out.println("IOException: " + ioe);
    }
  }
}
```


SaveableFrame (Code to Send Frame to Client on Network)

- **FrameServer.java**

```
public void listen(int port, SaveableFrame frame) {
  try(ServerSocket listener = new ServerSocket(port)) {
    Socket server;
    while(true) {
      server = listener.accept();
      frame.sendFrame(server.getOutputStream());
      server.close();
    }
  } catch (IOException ioe) {
    System.out.println("IOException: " + ioe);
    ioe.printStackTrace();
  }
}
```

SaveableFrame (Base Code to Get Frame)

- SaveableFrame.java

```
public static SaveableFrame getFrame(InputStream rawIn) {
  SaveableFrame frame = null;
  try(ObjectInputStream in =
        new ObjectInputStream(rawIn)) {
    frame = (SaveableFrame)in.readObject();
    frame.setVisible(true);
    return(frame);
  } catch(IOException ioe) {
    System.out.println("Error reading file: " + ioe);
  } catch(ClassNotFoundException cnfe) {
    System.out.println("No such class: " + cnfe);
  }
  return(frame);
}
```


SaveableFrame (Code to Get Frame from File)

- SaveableFrame.java

```
public static void main(String[] args) {
  SaveableFrame frame;
  File serializeFile = new File(serializeFilename);
  if (serializeFile.exists()) {
    try(FileInputStream fileIn =
          new FileInputStream(serializeFile)) {
      frame = getFrame(fileIn);
    } catch(IOException ioe) {
      System.out.println("IOException: " + ioe);
    }
  } else {
    frame = new SaveableFrame();
  }
}
```

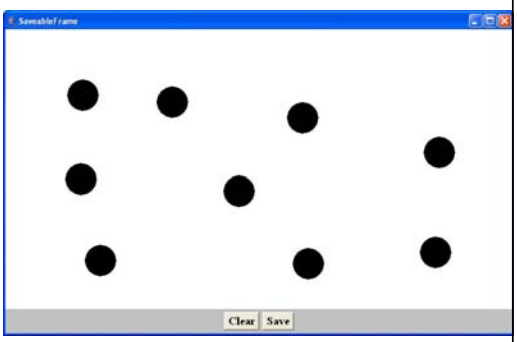
SaveableFrame (Code to Get Frame from Server on Network)

- **FrameClient.java**

```
public FrameClient(String host, int port) {
  try(Socket client = new Socket(host, port)) {
    SaveableFrame frame =
      SaveableFrame.getFrame(client.getInputStream());
  } catch(UnknownHostException uhe) {
    System.out.println("Unknown host: " + host);
    uhe.printStackTrace();
  } catch(IOException ioe) {
    System.out.println("IOException: " + ioe);
    ioe.printStackTrace();
  }
}
```


Results: SaveableFrame (Serialization to/from File)

- **Saving to File**
  - Open frame (600x400, no circles, top left corner)
  - Move window around
  - Resize it
  - Click to add circles
  - Press "Save"
- **Next time program runs**
  - Frame pops up at previous location, with previous size, including previous circles

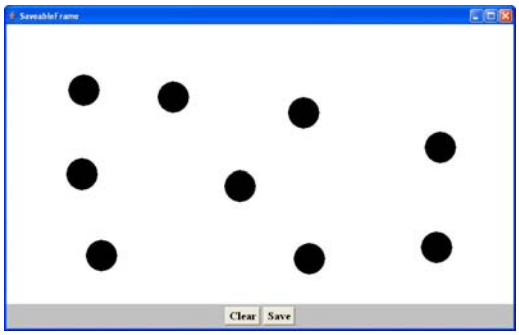


Results: SaveableFrame (Serialization to/from Network)

- **Machine 1**

```
DOS> java FrameServer 8888
```

  - Open frame (600x400, no circles, top left corner)
  - Move window around
  - Resize it
  - Click to add circles



- **Machine 2**

```
DOS> java FrameClient coreservlets.com 8888
```

  - Frame pops up with same location, size, and circles as version on the server

Wrap-Up

Summary

- **Class format**
  - Make sure custom classes implement Serializable and parent (non-Serializable) class has zero-arg constructor
    - Object is already Serializable
- **Sending data**
  - Wrap an ObjectOutputStream around a raw OutputStream
  - Call writeObject(objectYouWantToSend)
    - You need to use try/catch blocks
- **Receiving data**
  - Wrap an ObjectInputStream around a raw InputStream
  - Call readObject
  - Cast the result to desired type
    - You need to use try/catch blocks

Questions?