**CS 349**

Jeff Avery

* Assignments: 40%
* 10%, 10%, 10%, 10%
* Midterm: 20%
* Thurs June 9 @ 7:00 PM – 8:50 PM (location TBD)
* Final: 40%
* Scheduled by the Registrar’s Office

To pass the course, you must pass the weighted exam average and the weighted assignment average

Definition: User Interface

A user interface is the place where a person expresses intention to an artifact, and the artifact presents feedback to the person.

Interactive System Architecture

Model-View-Controller (MVC)

Graphical Temperature Control

Speech Temperature Control

Interface vs. Interaction

* What is the difference between an interface and interaction?
* Interface refers to the external presentation to the user
* Controls (what you can manipulate to communicate intent)
* Visual, physical, auditory presentation (what the program uses to communicate its response)
* Interaction is used to connote behavior: The actions the user must invoke to perform a task and the corresponding responses
* Interaction is action and dialog
* Unfolds over time

Interaction Design

* Challenging because of variability in users and tasks
* Varying levels of expertise among users
* Often a range of tasks will performed with the same tool (i.e. tools can be generic) – can you anticipate all uses and scenarios?
* No one “right way” to design an interface; interfaces can always be improved.
* Pushing technology “forward” requires us to rethink interaction.
* Emergence of UX as a discipline

Why Study Interaction? Empowering People

* Well designed interfaces empower people to do things they couldn’t otherwise do
* Desktop publishing, grassroots journalism (blogs), movie production, music production, image editing, assistive technologies...
* Interaction is the key to enabling new technologies
* Multi-touch and gestures on smartphones
* Voice interfaces for cars, watches
* A well designed tool can literally change the world
* The web browser, Linux, original Napster, the spreadsheet, email, instant messaging...

**GUI Basics and Windowing Systems**

*Using X Windows as a case study*

Evolution of GUI Programming

* On early computers, everything was "rolled by hand"
* Re-inventing the wheel with every iteration
* Interaction was very, very limited
* No graphical input or output
* Ivan Sutherland Sketchpad system
* No standards for interaction
* Leading up to the 1980's, researcher and industry began to develop GUI architectures and systems to simplify programming
* The Macintosh was the first successful commercial GUI, but there were a large number of competing systems introduced in the 80s and 90s!

Evolution of GUIs

* Xerox Star (1981)
* Developed at Xerox PARC
* Not commercially successful
* Apple Macintosh (1984)
* Inspired by Xerox PARC
* Commercial hit!
* Amiga Workbench (1985)
* Limited success
* Microsoft Windows 1.0 (1985)
* Limited success, led to Windows 3.0/3.1

X Windows (X11) System

X Windows

* Developed in 1984 (based on MIT Athena project)
* emerged as standard windowing system for Unix
* Free and cross-platform (OS, processor agnostic)
* one of the most successful free-software projects, ever
* Base windowing system, separate from operating system.
* not a window manager (more on that later)
* does not specify the style of user interface
* What does it do?
* a protocol to create windows, handle input, draw graphics
* a standard for low-level graphical output and user input

X Windows Design Criteria (~1986)

1. implementable on a variety of displays
2. applications must be device independent
3. must be network transparent
4. support multiple, concurrent application displays
5. support many different applications
6. support output to overlapping windows (... even when partially obscured)
7. support a hierarchy of resizable windows (... an application can use many windows at once)
8. high-performance, high-quality text, 2-D graphics, imaging
9. system should be extensible

Displays, Screens, Windows

* In X, a display may have multiple screens
* A display may have multiple windows
* a window may cross multiple screens

X Client-Server Architecture

* Separate user interface and application:
* the X Client handles all application logic
* the X Server handles all display output and user input
* a server handles requests from multiple clients, processes data as requested, and returns the results to the clients
* X inverts conventional www server/client relationship
* in www, web browser is the "client", web site is the "server"

Why Client-Server?

* goal was flexibility and economy
* many clients (perhaps multiple machines) running applications
* one display used to monitor the apps

X Windows as MVC Architecture

Structure of a Typical X Program

1. perform client initialization
2. connect to the X server
3. perform X related initialization
4. event loop:

* get next event from the X server
* handle the event:
* if the event was a quit message, exit the loop
* do any client-initiated work
* send drawing requests to the X server

1. close down the connection to the x server
2. perform client cleanup

Xlib (X Windows Library)

* library to wrap low level X Window protocol
* to avoid implementing message passing for every new program
* Xlib is not a window manager
* Xlib does not specify style of user interface or provide "widgets"
* uses buffered input and output queues
* need to flush them: XSync, XFlush
* Xlib functions:
* connection operations: e.g. XOpenDisplay, XCloseDisplay, ...
* connection operation requests: e.g. XCreateWindow, XCreateGC,...
* connection information requests: e.g. XGetWindowProperty, ...
* local event queue operations: e.g. XNextEvent, XPeekEvent, ...
* local data operations: e.g. XLookupKeysym, XParseGeometry, XSetRegion, XCreateImage, XSaveContext, ...
* Xlib data types:
* e.g. Display, Window, GC, XSizeHints, XWhitePixel, etc.

Display a Window (openwindow.min.cpp)

Opening a Window in Java

Recap: X Windows Design

* much of the XWindows architecture was influenced by its time period
* larger server machines and low-cost client displays because computation was expensive
* as computation git cheaper, certain aspects of program behaviour could be assumed:
* software runs on the client computer
* OS handles display rendering and has device drivers to coordinate with specific hardware
* over time, in a multi-OS world, even this restriction became a burden:
* services could be abstracted even farther from the underlying architectures, and programs could run on virtual machines (e.g. JVM, .NET VM, etc.)
* write once for a generic 'virtual' architecture, tun the program on the virtual machine
* any platform for which the 'VM' is implemented could execute the same program

**Intermission**

*How to run X11 sample code.*

Windows: C++ Examples

* On Windows, you can use Virtual Box and Linux for Xlib examples
* Install virtual box, download Ubuntu (or another linux distro) as an ISO
* Open Virtual Box and create an Ubuntu Linux VM
* Select, but do not start, and update IDE secondary master to point to Linux ISO
* Start VM and install should proceed
* Then
* Install g++ with
* sudo apt-get install g++
* Install X11 dev options with
* sudo apt-get install libx11-dev

Windows: VM Setup

* You may wish to map a local directory onto a subdirectory in my home directory as follows:
* Install Guest Additions from the Devices menu of the VM
* On your local machine create a folder
* From Machine > Settings > Shared Folders click the add icon and create a new directory pointing to that folder.
* Check the auto-mount and make permanent options
* On your host OS, make sure that the folder permissions make it accessible
* Create a symbolic link to /media/ to a subdirectory of your home directory.

Mac & Linux: C++ Examples

* On Mac OS X, this is much simpler:
* Install a version of the X Window System (Xquartz) from http://www.xquartz.org
* On Linux, this is trivial:
* You’re already running X. Just compile your code.
* Samples posted on the course website, along with a makefile (pay attention to the include for the X11 libs!)

**Windowing Systems**

*Windowing Systems, Basic Drawing, Events (Event Loop, Animation, Double-Buffering)*

Before Windowing Systems

X Windows Design Criteria (~1986)

* implementable on a variety of displays
* applications must be device independent
* must be network transparent
* support multiple, concurrent application displays
* support many different application and management interfaces
* support output to overlapping windows (... even when partially obscured)
* support a hierarchy of resizable windows (... an application can use many windows at once)
* high-performance, high-quality text, 2-D graphics, imaging
* system should be extensible

How to support multiple windows?

Base Window System (BWS)

* Lowest level abstraction for windowing system
* Routines for creating, destroying, managing windows
* Routes input to correct window
* Ensures only one application changing frame buffer (video memory) at a time
* one reason why single-threaded / non-thread-safe GUI architectures are popular
* Creates canvas abstraction for applications
* Applications shielded from details of frame buffer, visibility of window, other application windows
* Each window has its own coordinate system
* BWS transforms between coordinate systems
* Each window does not need to worry where it is on screen, always assumes its top-left is (0,0)
* Provides basic graphics routines for drawing

Window Manager

* Provides conceptually different functionality
* Layered on top of Base Window System
* Provides interactive components for windows (menus, close box, resize capabilities)
* Creates the “look and feel” of each window
* Application Window vs. Application “Canvas”
* the window manager owns the window (including its controls)
* the application owns the canvas

BWS vs. Window Managers

* Separation of Base Window System (BWS) from Window Manager (WM)
* Enables many alternative “look and feels” for the windowing system (e.g., KDE, GNOME...)
* One of the keys to its lasting power: can innovate by changing the WM layer
* Resiliency, since BWS and WM are separate processes
* OSX, Windows combine “BWS” and Window Manager
* Trade-offs in approaches?
* Look and feel...
* Window management possibilities...
* Input possibilities...
* Conceptually, on both platforms, there is a separation of canvas (assigned to application) and window decoration/OS overlay handled by window manager
* Lines do blur when combined, however
* e.g. Windows fast access menu-bar in the window frame

Motif (Stacking)

DWM (tiling)

Win (compositing)

## Getting Started with Git

Introduction to version control, Benefits of using Git, Basic commands, Workflow

Version Control Systems

* Goal of a Version Control System
* Software that manages changes that you make to your files (source code)
* track versions of each file (more accurately, versions of sets of changes to your files)
* handles concurrent changes from multiple sources (e.g. different developers working on the same code base).
* typically some central repository that stress every version of every file.
* Popular VCS'
* SourceSafe (local/file based)
* CVS, Subversion, Perforce (centralized)

Distributed Version Control

* Distributed version control systems (DVCS)
* No central server required!
* Every user has a copy of every file.
* We use Git, a very popular DVCS.
* Developed in 2005, to manage development for the Linux kernel (Bitkeeper -> Git)
* Very specific design goals
* Large-scale development
* Distributed
* Git doesn’t require a server, but it’s common to use one for coordination
* e.g. Github

Concepts

* Working directory
* your local copy of the files that you’re working with.
* Stagingarea
* a “place” where you tell Git to hold a set of changes, temporarily.
* Repository
* a place where Git stores copies of your files and their history.
* Local repository: on your working machine
* Remote repository: a server (e.g. GitHub)

Commands

* You perform these operations using a Git client (command- line or GUI, the work the same).
* Commands typically move files between working directory, staging area and local or remote repository.
* local Commands:
* git add: add a file from working directory to staging area
* git commit: commit changes from staging area to repo
* git checkout: get files from repo to working directory
* Remote Commands:
* git clone: make a copy from remote repo to working dir
* git pull: pull (merge) changes from repo to working dir
* git push: push (merge) changes from staging area to repo

Installing Git

Before anything else, you need to install and configure Git.

* Install a Git client (command-line or GUI)
* Set up your email address for Git: git config --global user.email "your\_email@example.com"

Working on A0

1. Get a copy of the repository from the server

* Use ‘git clone’ to get a copy of starting code from remote repository to your working directory.
* git clone https://@git.uwaterloo.ca/cs349- spring2016/.git

1. Work on the assignment

* copy the Check.java file into your working directory.
* ‘javac Check.java’ to compile
* ‘java Check’ to run and produce results.txt

1. Save and commit your changes to git

* ‘git add Check.java results.txt’ to add files to your staging area
* ‘git commit’ to save the changes to the local repository.

1. Push changes to the server

* ‘git push’ to push to the remote repository.

Good Ideas

1. Edit .gitignore file in your working copy
2. Consider cloning via SSH or HTTPS.

* For SSH, generate public/private keys
* if you use HTTPS, you might want to cache credentials

1. learn how to use tags or branches

**Java GUI Program**

*A quick-start guide to building Swing applications. With examples and pictures.*

Background

* Designed by James Gosling
* Released by Sun Microsystems in 1995.
* Originally a proprietary license, but made open source under GNU GPL in 2007.
* Sun and Java acquired by Oracle in 2010.
* General-purpose, portable language.
* Cross-platform, and able to scale from small devices to large applications.
* Dynamic, interpreted\*
* Broadly adopted, and extremely successful.
* “Java is TIOBE's Programming Language of 2015!” (www.tiobe.com)

Object Oriented

* C++ syntax
* Meant to be familiar to legions of C++ developers that would migrate to Java.
* Class-based, object-oriented design.
* Explicitly object-oriented
* Cannot build procedural applications!
* Extensive class libraries included
* Cross-platform!
* Support for everything from threading to database access to building user interfaces.
* This makes Java unique; many languages rely on third-party libraries.

Java Virtual Machine (JVM)

* Portability is achieved through virtualization
* Java compiles to bytecode (IR).
* Bytecode is executed by a Java virtual machine (JVM) on the target platform.
* Interpreted bytecode is slower than native code BUT just-in-time compilation can give near-native performance.

Installing the platform

* There are two main Java implementations
* Oracle Java: https://docs.oracle.com/javase/8/
* Open JDK: FOSS implementation for Linux.
* JRE: standalone JVM installation (runtime).
* JDK: JRE plus development tools and libraries.
* This gives you command-line tools (javac compiler and java runtime).
* Third-party support is excellent
* Editor support in VIM, Sublime, etc.
* IDEs like IntelliJ, Eclipse.

Java Platform (JDK): Includes tools, and libraries - everything from threading, to database access, to UI toolkits – all cross platform and portable.

Java SE API:

* user interface Toolkits: AWT, Swing, Java 2D, Accessibility, Drag n Drop, Input Methods, Image I/O, Print Service Sound
* integration Libraries: IDL, JDBC, JNDI, RMI, RMI-IIOP, Scripting
* other base libraries: Beans, Int'l Support, Input/Output, JMX, JNI, Math, Networking, Override Mechanism, Security, Serialization, Extension mechanism, XML JAXP
* lang and util Base Libraries: lang and util, Collections, Concurrency Utilities, JAR, Logging, Management, Preferences API, Ref Objects, Reflection, Regular Expressions Versioning, Zip, Instrumentation

JRE: includes Java SE API

* RIAs: Java Web Start, Applet / Java Plug-in
* Java Virtual Machine: Java HotSpot Client and Server VM

JDK: includes JRE

* Java Language: Java Language
* Tools & Tool APIs: java, javac, javadoc, jar, javap, JPDA, JConsole, Java VisualVM, Java DB, Security, Int'l, RMI, IDL, Deploy, Monitoring, Troubleshoot, Scripting, JVM TI

Building Applications

* Source code is written in text files ending with the .java extension (one class per source file).
* Source files are compiled into .class files (bytecode) by the javac compiler.
* Class files (.class) can be executed on any platform with an appropriate JVM.
* Often applications include many class files, which we bundle into a JAR (.jar) file (basically a zip file with metadata).

Command-Line Tools

* To compile on the command line: $ javac CountArgsApp.java
* To run compiled app: $ java CountArgsApp one two three You provided 3 args.
* This works when you have a single source file, but starts to fall apart when you have multiple files and dependencies (files that depend on one another).

Example Makefile

There's lots of robust build systems (Ant, Gradle) but we'll stick to makefiles for this course.

Syntax: make [target] $ make javac TestWindow.java $ make run java TestWindow

**The Java Programming Language**

*Language features, Classes and objects, Libraries, Program structure*

Standard Language Features

* Java uses the same syntax as C++ in most situations, so the style will be familiar.
* Variables: Standard naming conventions apply
* Operators
* Equality: == !=
* Assignment:= += -= and so on.
* Logical: not (!) and (&&) or (||) ternary(? :)
* Structure
* {} to nest blocks of code
* Control flow: if...else, while, break/continue.

Java Simple Types: see C++

Primitive types also have corresponding Object types (e.g. Boolean class for booleans, Integer for integers and so on.)

Java OO Features

Familiar OO features still apply to Java: (Feature / Description)

* Classes, objects: Types, instances of those types
* Dynamic dispatch: Objects determine type at runtime, instead of being static typed.
* Encapsulation: Data hiding
* Composition: Nesting objects
* Inheritance: Hierarchy of is-a class relationships
* Polymorphism: Calling code is agnostic in terms of whether an object is a derived or base class.

Java Class Structure

Variables

* Class variables: Shared among all static objects.
* Instance variables: Belong to an object instance.
* Member variables: All variables belonging to an object.

Methods

* Class methods: Shared among all static objects.
* Instance methods: Belong to an object instance.

Instantiating Objects

* In Java,
* Primitive types are allocated on the stack, passed by value.
* Objects are allocated on the heap, passed by reference
* Technically, value of address passed on the stack, but behaves like pass-by-reference.

Both refer to the same memory on the heap

Bicycle my\_bike = new Bicycle();

Bicycle kids\_bike = my\_bike;

* Practically, this means that you don’t need to worry about pointer semantics in parameter passing.

Pointer Gotchas!

Arrays are objects, so:

Bicycle[] bikeStore = new Bicycle[10];

// bikeStore[0].changeSpeed(25); //!!! Null pointer

for (int i = 0; i < 10; i++) {

bikeStore[i] = new Bicycle();

}

bikeStore[0].changeSpeed(25); //No problem

* First line allocates an array on the heap with space for 10 Bicycle pointers (40 bytes), but all Bicycle pointers are still null
* for loop allocates space for Bicycle to each entry in bikeStore array

Garbage Collection (GC)

* In Java, there’s no need to free memory
* Garbage collection runs periodically and frees up memory that’s not in use.
* JVM attempts to do this without impacting performance.

Inheritance

* Inheritance: increasing code reusability by allowing a class to inherit some of it’s behavior from a base class (“is a” relationship).
* Classes inherit common attributes and behavior from base classes.
* e.g. “Mountain Bike” is-a “Bike”.
* Common: speed,gear
* Unique: engine
* Use extends keyword.

Single Inheritance

* Java only supports single inheritance!
* In practice, this simplifies the language.
* See the “Diamond Problem” for one example of multiple inheritance being a hard problem.
* Solutions to this problem vary by language; Java just doesn’t let you do it.
* It’s very common to derive an existing Java Platform class and override behavior.
* All classes have Object as their ultimate base class (implicit).

Interfaces

* An interface represents a set of methods that must be implemented by a class (“contract”).
* Similar to pure abstract classes/methods.
* Can’t be instantiated
* Class implementing the interface must implement all methods in the interface.
* Use implements keyword.
* In Java,
* extend a class to derive functionality from it
* implement an interface when you want to enforce a specific API.

**Java Class Library**

*Packages, Class framework, Building GUIs with Swing*

Java Platform (JDK)

The Java Platform includes extensive cross- platform libraries to do everything from threading to database queries to user-interfaces.

Java Class Library

* Classes are grouped into packages (i.e. namespaces) to avoid name collisions.
* To assign your source code to a package, use the package keyword at the top of source files.
* Typically, package = subdirectory
* e.g. “graphics” package is in subdirectory of the same name
* alt. it can be included in a JAR file.
* For simplicity, samples and assignments won’t normally use packages.
* Use the import keyword to import a package
* This is how you include bundled Java libraries.

Common Classes/Packages (Classes(Examples) / Description)

* java.awt: Color, Graphics, Graphics2D, event.
* Contains all of the classes for creating user interfaces and for painting graphics and images.
* javax.swing: JFrame, JButton, JList, JToolbar
* Provides a set of "lightweight" (all- Java language) components that works the same on all platforms.
* java.io: File, FileReader, FileWriter, InputStream
* Provides for system input and output through data streams, serialization and the file system.
* java.lang: Boolean, Integer, String, System, Thread, Math
* Provides classes that are fundamental to the design of the Java programming language.
* java.util: ArrayList, HashMap, Observable
* Contains the collections framework, legacy collection classes, event model,...

Java Class Hierarchy

* Implicit class hierarchy
* All classes in Java are derived from the Object class in java.lang defines and implements common class behavior
* e.g. clone(), toString(), finalize() methods
* Classes you write inherit this basic behavior.

## Building Swing Interfaces

Widgets overview, creating a window, using Swing components, using listeners, PaintDemo

Widget

* Widget is a generic name for parts of an interface that have their own behavior: buttons, progress bars, sliders, drop-down menus, spinners, file dialog boxes. They are also called “components”, or “controls”.
* Widgets are typically packaged into libraries (toolkits) for reuse. Operating systems often bundle their own toolkits.
* Widgets have two main responsibilities:
* Widgets are responsible for drawing themselves, based on their current state.
* Widgets receive and interpret their own events (from BWS/WM or some container).

Java UI Toolkits

Java has four user-interface libraries, each with different types of widgets (and strengths/tradeoffs)..

Toolkit (Release): Description

* AWT (1995): “Heavyweight” with platform-specific widgets. AWT applications were limited to common-functionality that existed on all platforms.
* Swing (1997): “Lightweight”, full widget implementation. Commonly used and deployed cross- platform.
* Standard Window Toolkit / SWT (~2000): ”Heavyweight” hybrid model: native, and tied to specific platforms. Used in Eclipse.
* Java FX (~2010): Intended for rich desktop + mobile apps. Still in development.

Java AWT, Swing, SWT

* Java’s cross-platform goal required a decision:
* AWT, which supports the “lowest common denominator” of widgets across all supported platforms.
* Swing, which deployed a set of standard widgets (and behavior and look-and-feel) across all platforms.
* SWT, which provided close-to-native implementations, but are very platform specific (and difficult to port to new platforms).
* There are pluses and minuses to each approach.
* We use Swing exclusively for assignments.

Swing Component Hierarchy

* java.awt.Window is the base for all containers.
* javax.swing.Jcomponent is the root for all widgets.

How to use Swing

* Create a top-level application window, using a Swing container (JFrame or JDialog)
* Add Swing components to this window.
* Typically, you create a smaller container (like a JPanel) and add components to the panel.
* This makes dynamic layouts easier (more on that later in the course!)
* Add listeners for all events, like keyboard (press), mouse (down, up, move)
* Make components update and paint themselves based on input/events.

Java Listener Model

* To interact with components, add listeners which specify which events they should process.
* ActionListener is the most basic form
* We also have interfaces specialized by event type
* To use them, write a class that implements this interface, and override the appropriate methods

Adapters vs. Listeners

* Java also has adapters, which are base classes with empty listeners.
* Extend the adapter and override the event handlers that you care about; avoids bloat.

Anonymous Inner Classes

* We really, really don’t want to create custom adapters for every component.
* Solution? Anonymous inner class.

Swing UI Thread

* Swing needs to make sure that all events are handled on the Event Dispatch thread.
* If you just “run” your application from main, as we’ve been doing in the examples, you risk the main program accepting input before the UI is instantiated!
* Use invokeLater() to safely create the UI.
* We’ll discuss in greater detail later in the course.

PaintDeo.java

* PaintDemo is an example of a UI hierarchy.
* Demonstrates how to nest containers and components to build a more sophisticated application.
* Uses LayoutManager, which we will discuss later in the term.

**Drawing in Java**

*Graphics object, paint() method*

Graphics and Painting

* You can also draw using a series of primitive operators and the java.awt.Graphics object.
* Derive your top-level canvas from JComponent
* Override the paint() method
* Use the Graphics objects methods to set colors, draw lines, and so on.