Welcome!

~8 Lectures
- Slides posted on CS11 website
- [http://courses.cms.caltech.edu/cs11](http://courses.cms.caltech.edu/cs11)

~8 Lab Assignments (probably)
- Made available around Tuesdays
- Due one week later – Tuesday, 12 noon

Revised the Java track last time it was taught
- Bring it more into line with other tracks
- Cover more interesting topics and techniques
- Result: faster pace, may be 7 or 8 assignments
Assignments and Grading

- Labs focus on lecture topics
  - …and lectures cover tricky points in labs
  - Come to class! I give extra hints.

- Labs are given a score in range 0..3, and feedback
  - If your code is broken, you will have to fix it.
  - If your code is sloppy, you will have to clean it up.

- Must have a total score of 18/24 to pass CS11 Java
  - (or 75% of the possible points in the class)
  - Can definitely pass without completing all labs

- Please turn in assignments **on time**
  - You will lose 0.5 points per day on late assignments
Lab Submissions

- Using csman homework submission website:
  - [https://csman.cs.caltech.edu](https://csman.cs.caltech.edu)
  - Many useful features, such as email notifications
- **Must** have a CS cluster account to submit
  - csman authenticates against CS cluster account
- CS cluster account also great for doing labs!
  - Can easily do the labs on your own machine, since Java works the same anywhere
  - Just make sure you have Java 1.6+
Course Texts

- No textbook is required
- All necessary information is available online
  - Extensive Java API documentation
  - Java tutorials

- If you *really* want a book:
  *The Java Programming Language*, 4th ed.
  Ken Arnold, James Gosling, David Holmes
A Brief History of Java

- Created by Sun Microsystems starting late ’90s
  - Intended for embedded-systems programming
  - Primary goal was improving on C++
  - Renamed to Java in 1994
- Java 1.0 released in 1995
  - Versions 1.1, 1.2, 1.3, 1.4
- Numbering scheme changed with Java 5.0
  - (SDK/development version is still called 1.5)
- Current version is Java 6 (aka 1.6)
  - Java 7 is currently in Developer Preview
A Brief History of Java (2)

- Language, and standard libraries, have expanded dramatically over the years
  - Java 6 released in late 2006 – introduced many new language features, new APIs
  - More language/library changes planned for Java 7
- Java platform was made (mostly) open-source by Sun on May 2007
  - Allows Java platform to be ported to, and customized for, additional hardware platforms
- In Jan 2010, Oracle acquired Sun
  - Caused significant concern about future of Java
Design Goals of Java Language

- Simple and familiar
  - Based on C/C++, but with many subtleties removed

- Object-oriented
  - Well suited to distributed systems

- Architecture-neutral
  - Both source code and binaries are portable

- Dynamic loading and binding
  - Minimizes recompilations, and facilitates modularity!

- Secure
  - Class verification, code signing, permissions

- Multithreaded
  - Language specifies platform-neutral threading support
How Java Does Its Thing

- Source code goes into .java files.
- One top-level class per file.
- Class’ name dictates file name.

Example: HelloWorldApp.java

```java
// Display a message and then exit.
public class HelloWorldApp {
    public static void main(String[] args) {
        System.out.println("Hello, world! ");
    }
}
```
Java compiler takes `.java` files and compiles them into platform-independent `.class` files.

```
javac HelloWorldApp.java
```
produces `HelloWorldApp.class`

These class files contain byte-codes – instructions for the Java Virtual Machine (JVM).

Byte-codes for our example:

```
public static void main(java.lang.String[])
0: getstatic    #2;   //Field java/lang/System.out
3: ldc          #3;   //String "Hello, world!"
5: invokevirtual #4; //Method java/io/PrintStream.println
8: return
```
How Java Does Its Thing (3)

- Run the program with a **Java Virtual Machine (JVM)**
  - The JVM takes a class name, not the class’ filename
    ```
    > java HelloWorldApp
    Hello, world!
    ```

- The **java** program implements the JVM for a specific platform
  - Can run Java on any platform with a JVM implementation. (Windows, Linux, Solaris, MacOS X, …)

- Some JVMs improve performance by compiling Java byte-codes into native machine code
  - Called “just-in-time” compilation, or JIT for short
Java Comments

- **Java comments are just like C++ comments**
  ```
  /*
   * This method prints hello world.
   */
  public static void main(String[] args) {
    // This next part is tricky...
    System.out.println("Hello, world!");    // phew!
  }
  ```

- **Block comments can span multiple lines**
- **Single-line comments extend to end of line**

- **Nested /* */ comments don’t work!**
- **Block comments end with first */ encountered**
## Java Data Types

### Primitive Types

- **boolean**: values are **true** or **false**
- **char**: 16-bit unsigned integer (for Unicode characters)
- **byte**: 8-bit signed integer
- **int**: 32-bit signed integer
- **long**: 64-bit signed integer
- **float**: 32-bit signed floating-point value
- **double**: 64-bit signed floating-point value
More Java Data Types

■ Reference Types
  ■ Refers to an object (not a primitive type)
  ■ Can be null if the reference refers to nothing
  ■ Examples: String, Integer

■ In Java, arrays are also reference types
  ```java
  int[] numArray; // preferred!
  int numArray[]; // also works
  ```
  ■ More on arrays in a few weeks!
Notes on Java Literals

- Boolean is simply `true` or `false`
- Integer values are straightforward
  - `int i = 17;`
- Long values use “L” suffix:
  - `long secondsInYear = 31556926L;`
  - Avoid lower-case “l” – looks like 1 in many fonts…
- Default type of a decimal value is double
  - `double pi = 3.14159265358979323;`
- Float literal uses “F” suffix:
  - `float goldenRatio = 1.618f;`
  - In this case, either “F” or “f” is fine.
Java Character and String Literals

- Character literals can be single-quoted characters, or numbers between 0 and 65535
  
  ```java
  char capA = 'A';  // preferred
  char capA = 65;  // harder to maintain
  ```

- String literals are double-quoted
  
  ```java
  String sandwichType = "pastrami";
  ```

- Special characters must be escaped:
  
  ```java
  String msg = "He said, \"Java is neat!\"";
  ```

  - Most useful special characters:
    - \t = tab
    - \r = carriage return
    - \n = new line
    - \\ = backslash
    - \' = single quote
    - \" = double quote
Java Names and Naming Conventions

- Names must start with a letter, and can include only letters and digits
  - _ and $ are also considered “letters” in Java
  - Don’t use $ - used by compiler for auto-generated code
- Capitalization is very important in Java coding style
  - Fields and methods should follow camelCase naming convention
  - Classes and interfaces should follow UpperCamelCase naming convention
  - Package names should be all lowercase
- Java has a number of industry-wide conventions
  - Definitely want to learn them and follow them…
  - You must follow them in CS11 Java.
Java Variables and Initial Values

- Java variable declarations are like C/C++
  ```java
  int i;
  boolean err = false, done;
  String name = "Donnie";
  ```

- Local variables don’t have default initial values!
  ```java
  int i;
  i = i + 1;
  ➔ Compile-time error:
  variable i might not have been initialized
  ```
  - This is an example of Java’s focus on correctness
  - C or C++ would compile this code without errors
Primitive and Reference Variables

- Difference between primitive and reference types is where the value is actually stored
- Primitive variables:
  ```java
  int i = 20;
  int j = i;
  ```
  - Each variable stores its own value
- Reference variables:
  ```java
  String s1 = "Java!";
  String s2 = s1;
  ```
  - Value of reference variables is stored in main memory
  - Reference variables can refer to the same object
Java Operators

- Same set of operators as C and C++
  - Simple arithmetic:  +  -  *  /  %
  - Compound assignment:  +=  -=  *=  /=  etc.
  - Increment/decrement:  ++  --  (pre and post)
    ```java
    int i = 5;
    int j = ++i;  // j = 6, i = 6
    int k = i++;  // k = 6, i = 7
    ```
  - Comparisons:  ==  !=  >  >=  <  <=
    - Note: these operations produce boolean values!
    - In Java, no type can be cast to boolean (including int)
    - Also, boolean cannot be cast to any other type
Logical Boolean Operators

- Again, same as C/C++: `&& || !`
  - Logical AND, logical OR, and logical NOT.
- These operators require boolean values, and produce boolean values.
- Lazy evaluation:
  - For example: `name != null && name.equals("Donnie")`
    - `name.equals(...)` only evaluated if `name != null`
  - Conversely: `name == null || !name.equals("Donnie")`
- Precedence order: `! && ||`
String Operators

- String concatenation also uses + operator
  ```java
  public static void main(String[] args) {
      String name = "Donnie";
      System.out.println("Hello " + name);
  }
  ```
- At least one operand must be a String for + to do string-concatenation.
  - + operator is evaluated left-to-right
    ```java
    int i = 5;
    int j = 4;
    System.out.println("i = " + i); // Prints "i = 5"
    System.out.println(i + j); // Prints "9"
    System.out.println("i + j = " + i + j); // "i + j = 54"
    System.out.println(i + j + " = i + j"); // "9 = i + j"
    ```
Flow Control in Java

- Flow-control statements nearly identical to C/C++
  
  ```java
  if (cond) {
    statement;
  } else if (cond) {
    statement;
  } else {
    statement;
  }
  
  while (cond) {
    statement;
  }
  
  do {
    statement;
  } while (cond);
  ``

- Difference: `cond` must produce `boolean` value!

- Blocks of statements are enclosed with curly-braces `{ }`, just like in C/C++
  
  ```java
  if (cond) {
    statement1;
    statement2;
  }
  ```
Java For-Loops

- For loops are also very similar to C++
  - Initialize (and possibly declare) one or more looping variables
  - Test some condition before each iteration of the loop
  - Apply one or more updates to the looping variable(s)
    ```java
    for (init; condition; update) statement;
    ```
    - Equivalent to `while` loops, but more compact.
      ```java
      int i = 1;
      while (i <= 10) {
        sum += i;
        i++;
      }
      ```
      ```java
      for (i = 1; i <= 10; i++)
        sum += i;
      ```
More For-Loops

- Can specify multiple initial values:
  ```
  int i, sum;
  for (i = 1, sum = 0; i <= 10; i++)
    sum += i;
  ```

- Can declare loop variables in for-loop:
  ```
  int sum = 0;
  for (int i = 1; i <= 10; i++)
    sum += i;
  ```

  In this example, \textit{i} is only visible within the for-loop.
  The scope of \textit{i} is within the for-loop.
Even More For-Loops

- Can specify multiple update operations:
  ```
  int sum = 0;
  for (int i = 1; i <= 10; sum += i, i++) /*nothing*/;
  ```
  Document that the for-loop doesn’t need a body!

- Even more compact:
  ```
  int sum = 0;
  for (int i = 1; i <= 10; sum += i++) /* nothing */;
  ```
  Difficult to maintain! Best to be avoided.
Java Methods – A Brief Overview

Methods return a value of the specified type.

Or they return no value, indicated by `void` keyword.

Methods can accept any number of arguments.

- “No arguments” is indicated with empty parens `()`, not `void`.

A method’s signature includes its name and its parameter-list.

Modifiers will be covered in a bit…
System.out.println("Hello!");

Many flavors:

- System.out.println(String x)
- System.out.println(boolean x)
- System.out.println(char x)
- System.out.println(float x)
- System.out.println(int x)
- System.out.println(Object x)
- System.out.println()

- and a few more...

- These are **overloaded** methods.
  - Same name, but different signature.
Java Console IO

- **System.out** is the standard output stream
- **System.err** is the standard error stream
  - Use this to report errors when bad things happen.

- **System.in** is the standard input stream
  - We will use this next week.

- **System.out.println(...)** goes to next line
- Use **System.out.print(...)** to stay on same line
A Note About Class Names

- Java classes can be grouped into packages
  - This is optional, but typically very helpful!
  - Packages form a hierarchy

- `package1.package2.ClassName`
  - Package names are typically all lower-case
  - Naming rules are same as variable names.
  - Example: `java.awt.event.MouseEvent`

- More details on this later!
Terminology: Classes and Objects

- Java is *entirely* object-oriented programming (OOP) language
  - Programs are *entirely* composed of classes
- **Objects** are a tight pairing of two things:
  - **State** – a number of related data values
  - **Behavior** – code that acts on those data values in coherent ways
- **A class** is a “blueprint” for objects
  - The class defines the state and behavior of objects of that class
  - Actually defines a new **type** in the language
Terminology: Fields and Methods

- A class is comprised of **members**

- **Fields** are variables associated with the class.
  - They store the class’ state.

- **Methods** are operations that the class can perform.
  - A class’ set of methods specifies its behavior
  - The actual code for a method is its **implementation**
  - These methods generally (but not always) involve the class’ fields as well
Special Methods

- **Constructors** create new instances of a class.
  - Can take arguments, but not required. No return value.
  - All classes have at least one constructor.

- **Accessors** allow internal data to be retrieved.
  - Provides control over how data is exposed.

- **Mutators** allow internal data to be modified.
  - Provides control over how and when changes can be made.

- No destructors in Java!

- Not all classes have accessors and mutators.
Abstraction and Encapsulation

**Abstraction:**
- Present a clean, simplified interface
- Hide unnecessary detail from users of the class (e.g. implementation details)
  - They usually don’t care about these details!
  - Let them concentrate on the problem they are solving.

**Encapsulation:**
- Allow an object to protect its internal state from external access and modification
- The object itself governs all internal state-changes
  - Methods can ensure only valid state changes
Access-Modifiers

- Can be used on classes, methods and fields
- Four access modifiers in Java
  - `public` – Anybody can access it
  - `private` – Only the class itself can access it
  - `protected` – We’ll get to this later…
  - Default access-level (if you don’t specify anything)
    - Called “package-private” access

- Protect implementation details by using access modifiers in your code!
public class Point2d {
    // Coordinates
    private double xCoord;
    private double yCoord;

    /** Two-argument constructor. **/
    public Point2d(double x, double y) {
        xCoord = x;
        yCoord = y;
    }

    /** Default constructor; initializes to (0, 0). **/
    public Point2d() {
        // Call 2-argument constructor
        this(0, 0);
    }

    public double getX() { return xCoord; } // Accessors
    public double getY() { return yCoord; }

    public void setX(double x) { xCoord = x; } // Mutators
    public void setY(double y) { yCoord = y; }
}
Java Method Naming Conventions

- Java accessors usually start with `get`
  - `double getX()`
  - `double getY()`

- Java mutators usually start with `set`
  - `void setX(double)`
  - `void setY(double)`

- Accessors that return `boolean` often start with `is`
  - `boolean isRunning()`
  - `boolean isLoaded()`

- Exceptions are allowed when “is” doesn’t make sense:
  - `boolean contains(Object)`
  - `boolean intersects(Set)`
Using the Point

- Create a new `Point2d` object using the `new` operator
  
  ```java
  Point2d p1 = new Point2d();
  Point2d p2 = new Point2d(3.04, -5.612);
  ```

- Call methods on the `Point2d` objects
  
  ```java
  p1.setX(15.1);
  p1.setY(12.67);
  System.out.println("p2 = (" + p2.getX() + "," + p2.getY() + ")");
  ```
What are `p1` and `p2`?

```java
Point2d p1 = new Point2d();
Point2d p2 = new Point2d(3.04, -5.612);
```

- They are references to `Point2d` objects
- They are not objects themselves

### Juggling references:

```java
Point2d p3 = p1;    // Still only two objects
p1 = null;          // Both objects still reachable
p2 = null;          // One object isn't reachable!
```

JVM tracks when objects are no longer reachable

- “Garbage collection”
Object Method-Arguments in Java

- What happens when you call a function with an object argument?
  
  ```java
  public void printPoint(Point2d p)
  ```

- Remember, `p` is a reference to the object

- Reference is copied into `p`, but the `Point2d` object that it refers to is *not*

- Side-effects and funky bugs can easily occur!
void main(String[] args) {
    Point2d a =
        new Point2d(3.1, 2.4);

    printPoint(a);
}

void printPoint(Point2d p) {
    System.out.println(p.getX() +
        ""," + p.getY());
    p.setX(5.7); // ???
void main(String[] args) {
    Point2d a =
        new Point2d(3.1, 2.4);

    printPoint(a);
}

void printPoint(Point2d p) {
    System.out.println(p.getX() +
        "," + p.getY());
    p.setX(5.7);  // affects a
    p = new Point2d(-6.9, 0.7); // ???
}
void main(String[] args) {
    Point2d a =
        new Point2d(3.1, 2.4);

    printPoint(a);
}

void printPoint(Point2d p) {
    System.out.println(p.getX() + " ", " + p.getY());
    p.setX(5.7); // affects a
    p = new Point2d(-6.9, 0.7);
    p.setY(-2.1); // ???
}
void main(String[] args) {
    Point2d a =
        new Point2d(3.1, 2.4);

    printPoint(a);
}

void printPoint(Point2d p) {
    System.out.println(p.getX() + "," + p.getY());
    p.setX(5.7);  // affects a
    p = new Point2d(-6.9, 0.7);  // affects a
    p.setY(-2.1);  // local only
}
The Moral

- Be very careful with object-references
  - If a method accidentally changes an object, it can be very tricky to track down.

- Where reasonable, make objects immutable
  - Java has no equivalent to C++ `const` keyword!
  - An object is immutable if it provides no mutators
    - Set object’s state at construction time
    - Don’t provide any way to change the state
Method Magic

- Most methods have an *implicit* parameter **this**
  - **this** is a reference to the object being called
- Implicitly used when object fields or methods are accessed inside another method

```java
public double getX() {
    return xCoord;  // Same as "return this.xCoord;"
}

public String toString() {
    // Same as "this.getX()" and "this.getY()"
    return "(" + getX() + " " + getY() + ")";
}
```
Can also use `this` to resolve ambiguities

```java
void setX(double xCoord) {
    // xCoord is the parameter
    // this.xCoord is the object's field
    this.xCoord = xCoord;
}
```

Not an uncommon approach for mutators…
- Argument name is same as field name
- In general, avoid unnecessary ambiguities!
  - Can lead to very subtle bugs
Static Methods

- Some methods do not require a specific object
  - Called “static methods,” or “class methods.”
    ```java
    public static double atan2(double y, double x);
    ```
  - Static methods can’t use this reference
    - Method isn’t called on a specific object!
  - Specify ClassName.methodName()
- Non-static methods called “instance methods”
- java.lang.Math has only static methods
  ```java
  double tangent = Math.atan2(yComp, xComp);
  ```
Equality in Java

- Primitive types use `==` the way you would expect.
- For reference types, `==` compares the references themselves!
  ```java
  Point2d p1 = new Point2d(3, 5);
  Point2d p2 = new Point2d(3, 5);
  Point2d p3 = p1;
  
  Points p1 and p3 are the same object
  - p1 == p3 is true
  - p1 == p2 is false, even though values are the same
  
  Use `obj1.equals(obj2)` to test value-equality
  - Corollary: When you write classes, provide a reasonable implementation of the `equals()` method.
The `equals()` Method

- **Signature:**
  ```java
  public boolean equals(Object obj)
  ```

- **Returns true if** `obj` **is “equal to” this object**
  - Depends on what your class represents!
  - If `obj` is `null`, the answer is always “not equal”

- **Note that** `obj` **is a generic** `Object` **reference**
  - It could be any reference-type! Check that too.
  - The `instanceof` keyword lets you do this
Does `equals()` Make Sense?

- Reflexive:
  - `a.equals(a)` should return true

- Symmetric:
  - `a.equals(b)` should be the same as `b.equals(a)`
  - This can be tricky sometimes…

- Transitive:
  - If `a.equals(b)` is true and `b.equals(c)` is true, then `a.equals(c)` should also be true

- Nulls:
  - `a.equals(null)` should be false
Are These Points Equal?

```java
@Override
public boolean equals(Object obj) {
    // Is obj a Point2d?
    if (obj instanceof Point2d) {
        // Cast other object to Point2d type,
        // then compare.
        Point2d other = (Point2d) obj;
        if (xCoord == other.getX() &&
            yCoord == other.getY()) {
            return true;
        }
    }
    // If we got here then they're not equal.
    return false;
}
```
The `instanceof` Operator

- Use this to test an object’s type – its class
- Defined to return false if the reference is null
  - This is why we don’t need to check if the incoming object-reference is null.
Why `equals(Object)`?

- Classes can derive from other classes
  - Child class **inherits** all fields/methods of the parent class
  - Allows hierarchies of classes to be defined
  - Child class can be treated as its parent, since it has (at least) the same members as the parent class

- In Java, **all** classes derive from `java.lang.Object`
  - All objects can be treated as an instance of `Object`
  - `java.lang.Object` defines functionality that **all** Java classes should provide
    - `equals()`, `hashCode()`, `getClass()`, `clone()`, etc.
  - Example: can use `equals()` to compare **any** two objects
The Java API Documentation

- Complete API docs for the entire Java platform
  - Extremely useful, once you learn how to use it!
  - Auto-generated from Java library source-code
- Lists all classes and interfaces
  - How to use them
  - What features they provide
  - Their relationships with each other

- [http://java.sun.com/javase/6/docs/api/](http://java.sun.com/javase/6/docs/api/)
  - So useful, you might even want a local copy!
Other Useful Java Documentation

- The Java Tutorial
  - Different “trails” cover different topics
  - Very helpful resource for learning new features!

- Java Development Kit (JDK) Documentation
  - Feature-changes and new features
  - Tool documentation

- The Java Language Specification
- The Java VM Specification
This Week’s Homework

- Create your first Java program.
  - The CS11 object-oriented programming classic: Heron’s Formula
  - Create a 3D point class, add `equals()` and `distanceTo()` methods
  - Create another class that takes 3 points as input, and computes the area of the triangle using Heron’s Formula

- Learn how to compile and run your program.