Lecture Set 5: Design and Classes

This Set:
- Methods and Parameter Passing
- Basics of program design
- Pseudo-code
- Objects and classes
- Heaps
- Garbage Collection
- More about Creating Objects and classes in Java
- Methods
- Constructors, Accessors, Mutators
- Equality
- Printing an object

methods: defining and invoking

- One useful type of method for this project:
  - defined within the FlagMaker class
  - invoked from within another method that is defined in the same class
  - we’ll do a lot more variations later

- Defined based on a name and a list of parameters
  public static void name(parameterlist){
  body
  }

- Invoked by stating its name and giving an argument for each element of the parameter list
  name{argumentlist};

method information: parameters and arguments

- parameter list
  - type name for each item in the list
  - e.g. (MyGrid grid, char where)
- argument list
  - expression for each item in the list
  - e.g. (grid, 't')
- Matched between the arguments and the parameters based on position in the list
The Software Lifecycle

In the Real World, Requirements and Design Rule

- Getting requirements right is essential for successful projects
  - FBI electronic case file (junked after $180m)
  - IRS system upgrade in late 90s (junked after >$2bn)
  - FAA air-traffic control (false starts, >$10bn spent)
- Good design makes other parts of lifecycle easier
- In “the real world” coding typically < 30% of total project costs
- A good design improves:
  - efficiency (speed)
  - efficiency (memory)
  - ease of coding
  - ease of debugging
  - ease of expansion

Program Design

- There are many aspects to good design
  - Architecture
  - Modeling
  - Requirements decomposition
  - Pseudo-code
- In this class we will focus on latter
What Is “Pseudo-code”? 

- When developing a complex part of a program (an algorithm), one of the tools often useful is pseudo-code. 
- It's not English, not programming language -- somewhere between. 
- Captures the flow of the program without worrying about language-specific details.

Example:

- **Requirement**: email program that allows you to send a message either to one person, or to your whole address book.

- **Pseudo-code**: 
  
  ```plaintext
  prompt "Enter message: "
  input message
  prompt "Send to whole address book?"
  input answer
  if answer == "no"
    prompt "Enter recipient:"
    input recipient
    send message to recipient
  otherwise
    for each recipient, r, in address book
      send message to r
  ```

What Is Pseudo-Code? (cont.)

- NOT English
- NOT a program
- Something in-between
  - Captures the “logic” and “flow” of the algorithm
  - Note that pseudo-code could be translated into ANY programming language (not just Java)
- Good programming practice
  - Write pseudo-code first and keep it as your design
  - Include it as comments in your code to help you connect code to design
Testing

- Some testing is done by customer (acceptance testing)
  - E.g. testing we do on your projects!
  - You want to avoid errors surfacing during acceptance testing
- How to avoid errors during acceptance testing?
  - Test thoroughly before release
  - Cover all cases in code (if/else branches, etc.)
  - Identify "corner cases" (extreme values of inputs) and test with these
- We will study testing more later in semester

Questions

- What is `System` in `System.out.println()`?
- Why use `str.equals("cat")` to compare equality of `String str` and "cat"?
- Is the similarity of the notations
  - `System.out.println()`
  - `str.equals()`
  - `sc.nextInt()`
  - important, or coincidental?

Objects

- Bundles of (related)
  - data ("state")
  - operations ("behavior")
- Data often referred to as instance variables
- Operations usually called methods
- Invoking operations can change state (values stored in instance variables)
Sample Student Object

<table>
<thead>
<tr>
<th>State</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>getAge</td>
</tr>
<tr>
<td>ID</td>
<td>date</td>
</tr>
<tr>
<td>DOB</td>
<td>→ age</td>
</tr>
<tr>
<td>Major</td>
<td>getGrades</td>
</tr>
<tr>
<td></td>
<td>semester → grades</td>
</tr>
<tr>
<td>etc.</td>
<td>etc.</td>
</tr>
</tbody>
</table>

Accessing State / Methods

- If
  - o is an object
  - v is an instance variable of the object
  - m is a method of the object
  - Then
    - o.v is how to access the data v in o
    - o.m is how to invoke m in o
  - So
    - System is an object, with out an instance variable
    - out is also an object, with println a method
    - System.out.println is how to access this method!
- Suppose str is a String
  - str is an object!
  - Methods of this object: equals, compareTo, etc.
  - str.equals, str.compareTo, etc. invokes these methods on that object

Object-Oriented Programming

- Programs are collections of interacting objects
- Writing programs involves identifying what the objects should be and programming them
- Object-oriented languages provide features to ease object-oriented programming
- Defining objects involves indentifying
  - state
  - methods
Classes

- “Blueprints” (“templates”) for objects
- Classes include specifications of
  - Instance variables (including types, etc.) to include in objects
  - Implementations of methods to include in objects
- Classes can include other information also, as will be seen later
  - static methods / instance variables
  - public / private methods, instance variables
  - And so on

Student Class Example

Conceptually:
- Instance variables:
  - String name
  - int ID
  - int dateOfBirth
  - String major
- Methods
  - getAge
  - getGrades
  - etc.
- The actual class implementation will include code for the methods
- This describes a blueprint for student objects

How Are Objects Created?

- In Java: using `new`
  - Recall:
    - `Scanner sc = new Scanner (System.in);`
  - Invoking `new`:
    - creates fresh copies of instance variables in the “heap”
    - returns the “address” where the fresh variables are stored
- Heap? Address?
Heap = “Fresh Memory”

- While a program is running, some memory is used to store variables
  - Terminology: stack
  - We have been representing stack as table, e.g.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>5</td>
</tr>
<tr>
<td>y</td>
<td>4.5</td>
</tr>
</tbody>
</table>

- Rest of memory is called heap and can be used for other purposes, including storing new objects

Main Memory

- Stack grows, shrinks during program execution (why?)
- So does “allocated heap” (part of heap in use)
- Unallocated part of heap is called “free”

Object Creation

- New space allocated in heap to store instance variables
- Reference (= address) to this space is returned

Scanner sc = new (...);
Strings Are Objects

- Where is `new` in
  ```java
  String name = "Narita";
  ```
- Java provides it!
  - String is special because it is used so often
  - Java automatically "fills in" `new`
  - You can too:
    ```java
    String name = new String("Narita");
    ```

In Java, 9 Sorts of Variables

- 8 primitively typed
  - Types are the 8 built-ins (int, byte, double, etc.)
  - Storage allocated on stack based on type
  - Value stored in stack
    - e.g. `int x`
- Reference typed
  - Types are classes
  - Storage allocated on stack to hold one memory address (typically, one word)
  - What is stored in stack is reference to heap, where actual data is stored
    - e.g. `Scanner sc = new Scanner (System.in);`

Example

```java
int x = 7;
float y = 3.3;
String f = "cat";
```
Heap Issues

- What happens if `new` is called and there is no free heap?
  - Crash!
- What happens if following are executed?
  ```java
  String s;
  s = new String("cat");
  s = new String("dog");
  s = new String("cow");
  ```
- Wasted heap
  - "cat", "dog" no longer referenced by stack
  - Crashes become a problem!

Garbage Collection

- This "heap management" or "memory management" issue is central in CS
- Java copes by invoking garbage collector to reclaim unused but still-allocated heap space
- Garbage collector reclaims memory in allocated heap and returns it to free heap
- In previous example, "cat" and "dog" would be reclaimed

Example

```java
String a = new String("abc");
String b = new String("abc");
if (a == b) {
    println ("Equal");
} else {
    println ("Not equal");
}
```
- Not equal is printed
Contrasting Example

```java
String a = new String("abc");
String b = a;
if (a == b) {
    println("Equal");
} else {
    println("Not equal");
}
```

- Equal is printed
- This is called ALIASING: Two variables refer to same object.
- Can be DANGEROUS!!

```
String a = "abc"
```

```
str.equals()
```

```
Jan Plane (adapted from Bonnie Dorr)
```

Classes in Java

- Class declarations have the following form in Java:

```java
public class Student {
    // class body: instance variables, methods
}
```

- When you create a class in Eclipse, it generates this template for you

```
Visibility modifier:
```
Anatomy of an Instance
Variable Declaration

```
public int IDNum;
```

Anatomy of a Method Declaration (1)

... for methods that do not return values

```
public void acceptTokens(int tokensPassedIn){
    tokenLevel = tokenLevel + tokensPassedIn;
    ...
}
```

Anatomy of a Method Declaration (2)

... for methods that return values

```
public int lastFour(){
    ...
    return id % 10000;
}
```
Return Type

- Methods that return values must specify the type of the value to be returned
- The bodies of these methods use `return` to indicate when a value is to be returned
- The value being returned must have the same type as the return type

Object Creation

- Once a class is defined, objects based on that class can be created using `new`:
  ```java
class Student {
    String name;
    int id;
    int tokenLevel;

    Student(String nameDesired, int IDDesired, int tokensDesired) {
      name = nameDesired;
      id = IDDesired;
      tokenLevel = tokensDesired;
    }

    // Accessor methods
    String getName() { return name; }
    int getId() { return id; }
    int getTokens() { return tokenLevel; }

    // Mutator methods
    void setName(String newName) { name = newName; }
    void setId(int newID) { id = newID; }
    void setTokens(int newTokens) { tokenLevel = newTokens; }
  }

  public static void main(String[] args) {
    Student s = new Student("John Doe", 123456789, 3);
    s.setName("Jane Doe");
    s.setId(987654321);
    s.setTokens(5);
  }
```  
- To assign an object to a variable, the variable’s type must be the class of the object:
  ```java
  Student s = new Student();
  ```
- Each object has its own copies of all the instance variables in the class (except for certain kinds we’ll study later)
- Instance variables and methods in an object can be accessed using `.` or using setter (mutator) methods
  ```java
  Student s = new Student();
  s.IDNum = 123456789;
  s.setIDNum(123456789);
  ```

Constructors

- Special “methods” in class definitions to specify how objects are created
- Form of a constructor definition:
  ```java
  Student (String nameDesired, int IDDesired, int tokensDesired) {
    name = nameDesired;
    id = IDDesired;
    tokenLevel = tokensDesired;
  }
  ```
- Can have more than one constructor, provided argument lists are different
  ```java
  Student (int IDDesired) {
    id = IDDesired;
  }
  ```
- Java includes default constructor (no arguments), which you can redefine (override)
  ```java
  Student () {
    tokenLevel = 3;
  }
  ```
Equality Testing

- Need to define what it means for two students to be equal

```java
public boolean equals(Student otherStudent) {
    if (otherStudent == NULL) {
        return false;
    } else if (id == otherStudent.id) {
        return true;
    } else {
        return false;
    }
}
```

Objects to Strings

- What happens if we try to print a Student object?
  - Invoke `println` using a `Student` object as an argument?
    ```java
    Student s1 = new Student();
    System.out.println(s1);
    ```
  - Something like this prints:
    `Student@82ba41`

Java Knows “How” To Print Any Object

- Why?
  - Every class has a default `toString` method
  - `toString` converts objects into strings
  - `System.out.println` calls this method to print an object
  - Default: object type and address
- `toString` can be overridden!

```java
// The method for converting Students to strings
public String toString () {
    return (name + " ". + id);
}
```
Static Data Members and Static Methods

- Not contained in or associated with an object of that type
- Accessed by the ClassNamevariableName or by ClassName.methodName
- rather than by objectName.variableName or by objectName.methodName

Set / Get Methods

- We have been using = to modify instance variables and accessing variables directly to read values
- Generally, this is not good practice because it imposes restrictions on class implementation
- Better
  - set methods to set values (mutators)
  - get methods to read values (accessors)

Set Methods (Mutators)

```java
public void setId (int newID) {
    id = newID;
}
```

- Can also do consistency checking

```java
public void setTokenLevel (int newTokenLevel) {
    if (newTokenLevel <= 3) {
        tokenLevel = newTokenLevel;
    } else {
        System.out.println ("Bad argument to setTokenLevel: "+ newTokenLevel);
    }
}
```
Get Methods (Accessors)

- Sole purpose is to return values of state
  ```java
  public int getID () {
    return id;
  }
  ```
- Why use them?
  - The state information may not always be stored in a single instance variable, since implementations may change
  - You give designers option of changing instance variables