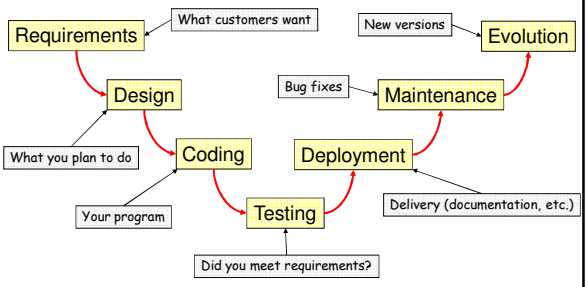
Lecture Set 5: Design and Classes

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

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

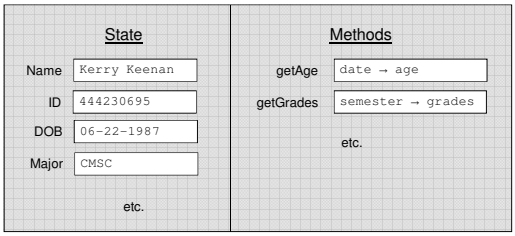
What Is "Pseudo-code"?

- 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.

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



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"

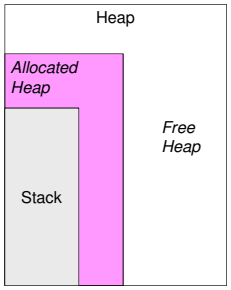
- While a program is running, some memory is used to store variables
  - Terminology: stack
  - We have been representing stack as table, e.g.

Variable	Value
x	3
y	4.5

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

Main Memory

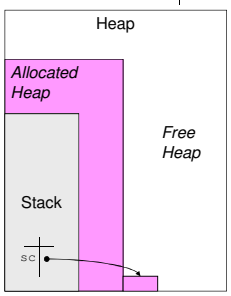
- Stack grows, shrinks during program execution (why?)
- So does "allocated heap" (part of heap in use)
- Unallocated part of heap is called "free"



Object Creation

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

```
Scanner sc = new (…);
```



Strings Are Objects

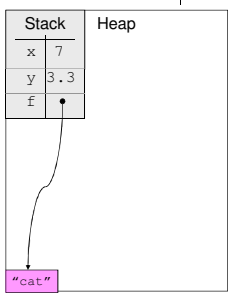
- Where is `new` in
  `String name = "Narita";` ?
- Java provides it!
  - `String` is special because it is used so often
  - Java automatically "fills in" `new`
  - You can too:
    `String name = new String("Narita");`

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

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

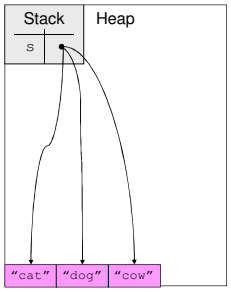


Heap Issues

- What happens if `new` is called and there is no free heap?
  Crash!
- What happens if following are executed?

```
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!



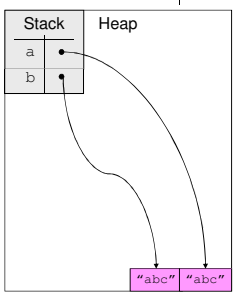
Garbage Collection

- 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

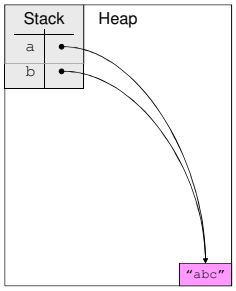
```
String a = new String ("abc");
String b = new String ("abc");
if (a == b) {
  println ("Equal");
} else {
  println ("Not equal");
}
```

- `Not equal` is printed



Contrasting Example

```
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!!
- What if we really want to make a copy?

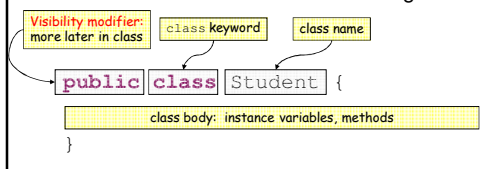
```
String a = "abc"
String b = new String(a);
```


"equals"

- == checks if two reference variables refer to the same object
- Methods like `str.equals()` check if two different objects have the same "content"
- Other classes will have an `equals` method also

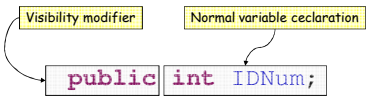
Classes in Java

- Class declarations have the following form in Java:



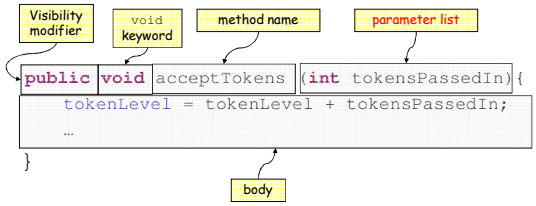
- When you create a class in Eclipse, it generates this template for you

Anatomy of an Instance Variable Declaration



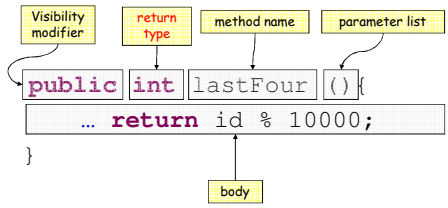
Anatomy of a Method Declaration (1)

… for methods that do not return values



Anatomy of a Method Declaration (2)

… for methods that return values



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`:

```
new Student ()
```

- To assign an object to a variable, the variable's type must be the class of the object

```
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

```
s.IDNum = 123456789;
s.setIDNum(123456789);
```


Constructors

- Special "methods" in class definitions to specify how objects are created
- Form of a constructor definition:

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

- Can have more than one constructor, provided argument lists are different

```
Student (int IDDesired) {
    id = IDDesired;
}
```

- Java includes *default* constructor (no arguments), which you can redefine (override)

```
Student () {
    tokenLevel = 3;
}
```

Equality Testing

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

```
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?

```
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!

```
// 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 ClassName.variableName 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)

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

- Can also do consistency checking

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

Get Methods (Accessors)

- Sole purpose is to return values of state

```
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