Object Oriented Programming
Objectives

• To learn/review the concepts and terminology of object-oriented programming

• To discuss some features of object-oriented design
Objects

• In Java and other Object-Oriented Programming (OOP) languages, the focus is on *objects*

• *Objects* are entities that can do actions or be acted upon in a Java program

• All objects have
  
  • *Properties*
    • These are the *data* about an object
    • In Java we call them *attributes* or *fields* or *instance variables*
  
  • *Behaviours* (*actions*)
    • In Java they are implemented as *methods* (more specifically, *instance methods*)
Objects and Classes

• Every object belongs to a specific class
  • Objects that belong to the same class have the same properties and can perform the same actions

• We can think of a class as being a template or pattern or model or definition for objects of that class
Object-Oriented Programming

- *Object-oriented programs* consist of *interacting objects*
  
  - Objects are *defined by* classes
  - Objects are *created by* objects of other classes (*client classes*) which *use* them in implementing a programming solution to a problem
Example: Social Networking

• Suppose we want to keep track of social contact information for our friends / relatives

• We wish to write a program that allows us to add contact information of a friend to our list of friends, remove a contact from the list, and print information about all our contacts.
Example: Social Networking

- Part of OOP design is deciding on what classes we will need for our problem
- Let's start with a class called **Person**, that will model the information about one person in our social network
Class Definition

• A *class definition* consists of
  • Attribute declarations
    (also known as *fields* or *instance variables*)
  • Constructor definitions
  • Method definitions
• A class definition is stored in a file
  • With the same name as the class
  • With a `.java` extension on the file
Example: Person Class

- **Attributes (instance variables, fields)**
  - What kind of information do we want to have about a person? Let’s keep it short for now
    - Person's name
    - Email address
  - What type should each of these be?
    - A name can be a string
    - An email address can be a string
Example Python: Person Class

class Person:
    
    def __init__(self, firstName="", lastName="", email=""):  
        self.firstName = firstName  
        self.lastName = lastName  
        self.email = email  

• Note in Python we can assign default values to the attributes in this case we used an empty string
Example Java: Person Class

public class Person{
    /* Attribute declarations */
    private String lastName;
    private String firstName;
    private String email;

    Why are the attributes private?
    Note that the instance variables are just being declared here (not explicitly assigned values)
Constructors

• A constructor is a special method that is called automatically when an object is created with the new operator
  • Its purpose is to initialize the attributes of an object when the object is created
  • In Python we use the special method __init__ to do the job of a constructor
  • In Java a constructor has the same name as the class name
Example: Person class

```java
/**
 * Constructor initializes the person's name
 * and email address
 */
public Person(String firstName, String lastName, String email) {
    this.lastName = lastName;
    this.firstName = firstName;
    this.email = email;
}
```

Compared to Python, in Java one must EXPLICITLY give types to the attributes. Also note the difference between the keyword `this` vs Python’s `self`. 
Terminology

• Keyword *this* similar to *self* in Python
• Scope of variables
  • *Scope* refers to the parts of the code in which those variables can be used
  • Scope of instance variables?
• Formal parameters
  • What is their scope?
Example: Person Class

• What *methods* might we want to have?
  • *accessor methods* (aka *getters*)
  • *modifier methods* (aka *setters*)
  • `toString` method (in Python this is `__repr__` or `__str__`
  • `equals` method (in Python this is `__eq__`)
    • two Person objects are the same if they have the same first name and same last name
**Example: Person class**

Java
```java
/**
 * setEmail method sets the person's email address
 * @param email
 */
public void setEmail (String email) {
    this.email = email;
}
```

Python
```python
    setEmail method sets the person's email address.
    :param email: email address to set
    def setEmail(self, email):
        self.email = email
```

Note that Python uses WHITESPACE to tie blocks of code together Java uses BRACES and SEMICOLONS (you should still code with whitespace as well)

What is this `@param`?
- **Javadoc documentation** (we will do it in Lab 2)
### Python

def __repr__(self):
    s = self.firstName + " " + self.lastName + "\t" + self.email
    return s

### Java

/**
 * toString method returns a string representation of the person
 * @return string with first name and last name, email address
 */
public String toString() {
    String s = this.firstName + " " + this.lastName + "\t" + this.email;
    return s;
}
Discussion

• What is the return type of this method?

• What is \t?

• What kind of variable is s?
  • A *reference variable* of type String

• What is its scope?
  • It is a *local variable*
**Python**

```python
def equals(self, other):
    if self.firstName == other.firstName and self.lastName == other.lastName:
        return True
    else:
        return False
```

**Java**

```java
/**
 * equals determines whether two persons have the same name
 * @param other: other Person object that this is compared to
 * @return true if they have the same first and last name, false otherwise
 */
public boolean equals(Person other) {
    if (this.firstName.equals(other.firstName) && this.lastName.equals(other.lastName))
        return true;
    else
        return false;
}
```

- What is `this.firstName`? `other.firstName`?
- Where is the `equals` method that is used in the code?
Example: SocialNetwork Class

• We are now ready to provide a class that allows us to keep track of our social contacts
• What attributes might it have?
  • A list of Person objects
    • We'll use an array as our data structure *(this is similar to the notation of a list in Python)*
  • A count of the number of friends currently in the list
    • Why is this not necessarily the same as the size of the array?
Example: SocialNetwork Class

Python:
from Person import Person
class SocialNetwork:
    def __init__(self,num=0):
        self.friends =[]
        self.numFriends =num

Java:
/* Attribute declarations */
// array of persons (list of friends)
private Person[] friendList;

//current number of friends in list
private int numFriends;
/* Constant definition */
private final int DEFAULT_MAX_FRIENDS = 10;

Notice in Python we declare the attributes in the constructor itself
Terminology

• Keyword *final* (no such thing in Python, by convention we used all capitalized words to represent a constant)

• Array declaration `[]` (array’s and python lists do NOT always act the same)
Example: SocialNetwork Class

• **Constructors:**
  • One that creates an array of default size
  • One that takes the size of the array as a parameter

• What do we call it when there is more than one constructor?
  • *overloading*

• *In Python we do this by setting defaults in the method*
Java:
/**
* Constructor creates Person array of default size
*/
public SocialNetwork () {
    friendList = new Person[DEFAULT_MAX_FRIENDS];
    numFriends = 0;
}

/**
* Constructor creates Person array of specified size
* @param max maximum size of array
*/
public SocialNetwork(int max) {
    friendList = new Person[max];
    numFriends = 0;
}

Python:
from Person import Person
class SocialNetwork:
    def __init__(self, num=0):
        self.friends = []
        self.numFriends = num

Notice how there is only one constructor for Python but it uses default values to allow for different uses of it.

Also note than in Java arrays must MUST have an specified size; lists can grow dynamically in Python.
Discussion

• What is stored in the `friendList` array after the following is executed?

```java
friendList = new Person[DEFAULT_MAX_FRIENDS];
```

• How does this differ from Python?

```python
self.friends = []
```
Example: SocialNetwork Object

contacts = new SocialNetwork(5);
Example: SocialNetwork Class

- **Instance methods**: let's start with methods to
  - add a person to the list
  - remove a specified person from the list
  - clear the list, i.e. remove all persons
  - return how many persons are in the list
  - `toString`
  - *(we will add other methods later)*
Java:

```java
/**
 * add method adds a person to the list
 * @param firstName
 * @param lastName
 * @param email
 */
public void add (Person friend) {
    // add it to the array of friends // but, what if array is not big enough?
    // double its capacity automatically
    if (numFriends == friendList.length)
        expandCapacity();

    // add reference to friend at first free spot in array
    friendList [numFriends] = friend;
    numFriends++;
}
```

Python:

```python
def add(aFriend):
    self.friends.append(aFriend)
    self.numFriends = len(self.friends)
```
Example: SocialNetwork Object

contacts = new SocialNetwork(5);

After 3 friends are added it will look like this:

Note that numFriends also acts as the index of the first free spot in the array!
Arrays

• An array has a particular number of cells when it is created (its \textit{capacity})
• What happens when an array is full and we try to store past the last element in the array?
  • An \textit{exception} is thrown
  • What happens then?
• We can instead \textit{automatically expand the capacity} of the array in our code!
/**
 * expandCapacity method is a helper method
 * that creates a new array to store friends, with twice
 * the capacity of the existing one
 */

private void expandCapacity() {

    Person[] largerList = new Person[friendList.length * 2];

    for (int i = 0; i < friendList.length; i++)
        largerList[i] = friendList[i];

    friendList = largerList;
}

Note in Python we did not have to do this as lists can
grow dynamically
Terminology

• Helper method
• Array length
• **Scope of variables**: what is the scope of each of the following variables?
  • friendList
  • largerList
  • i
**toString**

```java
/**
 * toString method returns a string representation of all persons in the list
 * @return string representation of list
 */

public String toString() {
    String s = ""
    for (int i = 0; i < this.numFriends; i++){
        s = s + this.friendList[i].toString() + "\n";
    }
    return s;
}
```

• What is "" ? "\n" ?

```python
def __repr__(self):
    s = ""
    for element in self.friends:
        s = s + element.getFriend()
    return s
```
Class SocialNetwork contains a method for removing a data item from the array. To remove a data item, say *target*, from the array we first need to find the position of such an item in the array. A simple way of looking for *target* in array *friendList* is to take the data items stored in the array one by one starting at the data item stored in index 0 and compare each one of them with *target* until either

- *target* is found, or
- all data items have been examined and *target* is not found

The above algorithm for looking for a data item in a list is called *linear search*.

Once item *target* has been found in the array we can remove it by replacing it with the last item in the array. Pseudocode for removing a data item from the array follows.
Algorithm remove(target)
Input: data item to be removed
Output: true if target was removed from the array; false if target was not found in the array

\[ i = 0 \]
\[ \textbf{while} \ (i < \text{numFriends}) \ \textbf{and} \ (\text{friendList}[i] \ \text{not equal} \ target) \ \textbf{do} \]
\[ \quad i = i + 1 \]
\[ \textbf{if} \ i = \text{numFriends} \ \textbf{then return} \ false \]
\[ \textbf{else} \ { \]
\[ \quad \text{friendList}[i] = \text{friendList}[	ext{numFriends} - 1] \]
\[ \quad \text{friendList}[	ext{numFriends} - 1] = \text{null} \]
\[ \quad \text{numFriends} = \text{numFriends} - 1 \]
\[ \quad \textbf{return} \ true \]
\[ } \]
The advantage of writing an algorithm in pseudocode is that we can concentrate on designing the steps that the algorithm needs to perform to achieve the desired task without having to think about how to express the algorithm in correct java syntax.

Once we have designed a correct algorithm for a problem in pseudocode, translating it into java is a somewhat mechanical process.

Writing algorithms in pseudocode and then translating them into java makes it easier to design programs.
The beauty of pseudocode is that there is no fixed syntax or rigid rules for it. Pseudocode is a mixture of English and programming-like statements.

Each programmer comes up with their own version of pseudocode. The programmer just needs to ensure that pseudocode is understandable to other people and that it is detailed enough that translation into java or other programming language is simple. There should be an (almost) one-to-one correspondence between lines of pseudocode and lines of java.

The java version for the remove algorithm follows.
public boolean remove(Person target) {
    // search the list for the specified friend
    int i = 0;
    while ((i < numFriends) && !friendList[i].equals(target))
        i++;

    if (i == numFriends) return false;
    else {
        // person found, remove by replacing with last one
        friendList[i] = friendList[numFriends - 1];
        friendList[numFriends - 1] = null;
        numFriends --;
        return true;
    }
}
Example: SocialNetwork Object

Suppose the target person to be removed was the first one (P1); after it is removed, we will have:

```
contacts
```

```
numFriends
```

```
friendList
```

```
2
```

```
P3
```

```
P2
```

2 Person objects

```
Discussion

• The search in the remove method is called a **linear search**
  • It starts at the beginning and continues in a sequential manner
• Where is the `equals` method of the line `friendList[i].equals(target)` defined?
Discussion

• Why is it OK to replace the reference to the found Person with the last one in the list?
Exercises

• Write `getNumFriends`
• Write `clearFriends`
Example: Using the SocialNetwork Class

Java:
```java
public class MyFriends {
    public static void main(String args[]) {
        SocialNetwork contacts = new SocialNetwork();
        contacts.add("Snoopy", "Dog", "snoopy@uwo.ca");
        contacts.add("Felix", "Cat", "felix@uwo.ca");
        contacts.add("Mickey", "Mouse", "mickey@uwo.ca");
        System.out.println(contacts.toString());
        System.out.println("I have ", contacts.getNumFriends(), " friends in my contact list");
    }
}
```

Python:
```python
def main():
    from SocialNetwork import SocialNetwork
    from Person import Person

    contacts = SocialNetwork()
    contacts.add("Snoopy","Dog","snoopy@uwo.ca");
    contacts.add("Felix","Cat","felix@uwo.ca");
    contacts.add("Mickey","Mouse","mickey@uwo.ca");
    print(contacts)
    print("I have ", contacts.getNumFriends(), " friends in my contact list")

main()
```
Discussion

• Note that if we had
  
  System.out.println(contacts);

then Java would automatically invoke the toString method of the class that contacts belongs to

• How many friends could you add to your list of friends, in an application program that uses our SocialNetwork class?
The second line in the above java class:

    public static void main (String[] args) {

states that method `main`, when invoked can receive any number of arguments. Java will create an array of the correct size to store the arguments. Java was designed so that the first method that is executed in any java program is `main`. The arguments that are passed to this method are called the `program arguments` or `command line arguments`.

The keyword `static` tells the java compiler that when the program is executed a special object, sometimes called a `static object`, needs to be created. Static objects are different from other objects in that they are not created by the programmer with the `new` statement. Since to run a java program, objects need to be created first, this solves the issue of how to create the very first object of a program.
Exercise: Expand the SocialNetwork Class

• The SocialNetwork class could use some more methods in order to be useful!
  • A method that writes the list to a file
  • A method that reads the list from a file
  • A method that searches for a particular friend in the list, and returns the email address
  • Others?
Passing Parameters

• Why are methods written with parameter lists?
  • So that the methods can be more general
    • We can use methods with different values passed in as parameters
Passing Parameters

• How are parameters actually passed?
• The variable in the parameter list in the method definition is known as a formal parameter
• When we invoke a method with a parameter, that is known as an actual parameter
When the `add` method is executed, the value of each actual parameter is **passed by value** to the corresponding formal parameter variable.
Aspects of Object-Oriented Design

• Modularity
• Information Hiding
• Encapsulation
Aspects of Program Design: Modularity

• **Modularity** refers to subdividing a large problem into smaller components, or **modules**, to make the design of a solution easier
  
  • Modules should be as independent from each other as possible
  
  • Each module should perform one well-defined task
Aspects of Program Design: Information Hiding

• *Information hiding* refers to making implementation details inaccessible
  • To users of a program (they do not need to know about implementation details)
  • To other modules in a program (they cannot see nor change the *hidden* details)
• Example: attributes (instance variables) in a class definition are *private*
  • What parts of a program can access instance variables directly?
Aspects of OOP Design: Encapsulation

- **Object-oriented Design** produces modular solutions
- We identify the components involved within the problem: the *objects*
  - An object has data: *characteristics (attributes)*
  - And *behaviours (operations)*
- Combining the *data* and the *operations on the data* is called *encapsulation*
  - They are combined in the class definition