COMP 202

Building Your Own Classes

CONTENTS:
- Anatomy of a class
- Constructors and Methods (parameter passing)
- Instance Data

COMP 202

- We've been using predefined classes. Now we will learn to write our own classes to define new objects.
- This week we focus on:
  - Objects: attributes, state and behaviour
  - Anatomy of a Class: attributes and methods
  - Classes as Types
  - Creating new objects
  - Parameter passing

Part 1

About Objects

Objects

- An object has:
  - *state* - descriptive characteristics
  - *methods* - what it can do (or what can be done to it)
    - » services, actions, behavior, ….
- For example, consider a bank client with a checking and a savings account.
- The state of the client is the balance of the checking and saving accounts.
- Methods are withdrawal, deposit and transfer, querying the balance etc.
- Some methods might change the state

Classes

- A *class* is a blueprint of an object
- It is the model or pattern from which objects are created
- For example, the `String` class is used to define `String` objects:

  Object Variable *Object*

  Class → String x = "Bob"; ← *State*
- Each `String` object contains specific characters (its state)
- Each `String` object has methods such as `toUpperCase`:

```
x = x.toUpperCase();
```

- In the case of `String`, the methods don't change the object itself; but this is very specific to strings

Classes

- The `String` class was provided for us by the Java standard class library
- But we can also write our own classes that define specific objects that we need
- For example, suppose we wanted to write a bank program that manages the clients and their saving and checking accounts.
- We could write a `Client` class to represent client objects with the two associated accounts.

Part 2

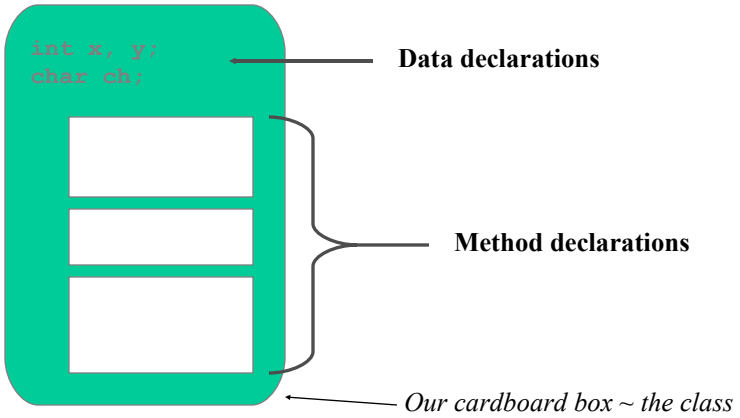
The Anatomy of a Class

The Anatomy

- A class can be considered to be a cardboard box containing items (called *members* in Java):
  - Constants
  - Variables
  - Methods
    - constructor methods (that help creating an object of the class)
    - other useful methods (withdraw, transfer)
    - possibly a main method
- Each item (data and method) in the box can be accessed and modified by using the DOT operator

Classes

- A class contains data declarations and method declarations (collectively called *members* of the class)

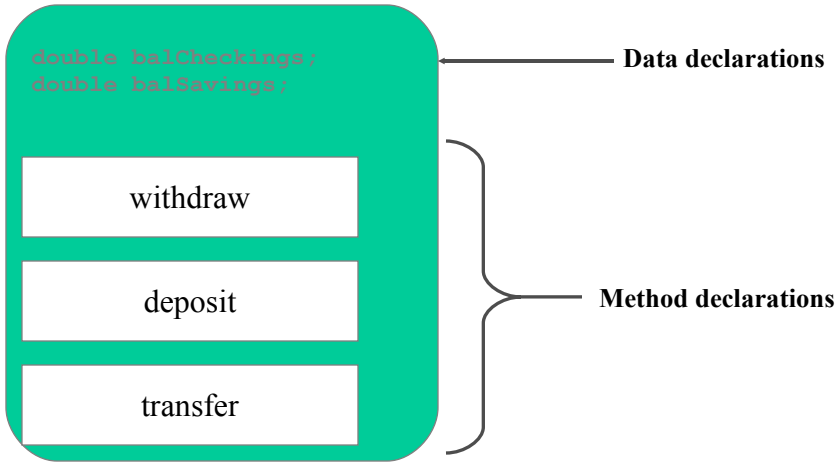


The Idea Behind A Class

- A class builds objects
- Each class, generally, represents a <u>real thing</u>, for example:
  - Class Client represents the properties and behaviour of a Client of a bank.
  - Object X of class Client represents an actual particular client.

Classes

- A client has a checking account and a savings account
  - Each is represented by its balance
- We can perform withdrawals, deposits, transfers…



Java Methods

- **Method: A set of statements that build a logical unit of action.**
  - Class method: (more about this later)
  - Instance method: (**let us focus on this one today**)
    - Any method that is invoked with respect to an instance of a class. Also called simply a *method*.
- Many methods need input (e.g. System.out.println("xxx");)
  - The inputs of a method are called its *parameters*.
    - Each parameter is of a certain type
- Many methods return output (e.g. scan.nextInt());
  - The output of a method is called its *return value*.
    - The return value is of a certain type
  - A method in Java does not have to return a value,
    - declare the return type as *void* (as in the `main` method).

Signature

```
String replace(char oldChar, char newChar)
```

Writing Methods

- A *method declaration* specifies the code that will be executed when the method is invoked (or called)

Method Header

optional Modifiers — *Type of return value* — *Input parameter*

```
public static void main(String args[])
{
        int x = 5;
        System.out.println(x);
}
```

Code body

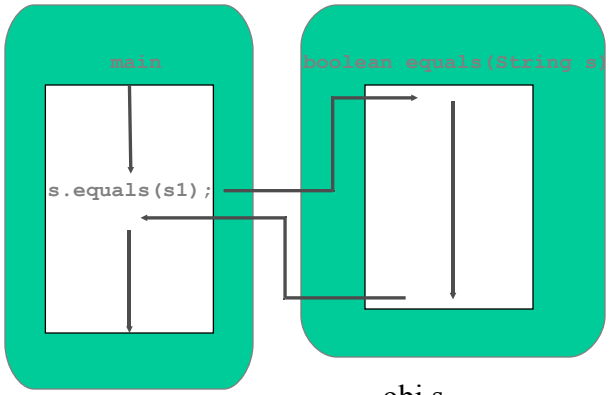
Method declaration

Method Invocation

- When a method is invoked, the flow of control jumps to the method and executes its code
- When complete, the flow returns to the place where the method was called and continues
- If the methods has a return value
  - we can assign this value to a variable of the appropriate type
  - we can use the method call as an operand in an expression

Method Calls

Syntax:
- OBJECT.METHOD(PARAMETERS);
- X = OBJECT.METHOD(PARAMETERS);



Method Locations

- Methods only exist within classes
- When you invoke a method, we say that the method is being *called*.
- Assume you are in `main` method of class X, then
  - you can call a method from another class Y
    - static method on class name (e.g. Math.abs(int i))
    - other methods on objects of class Y (e.g., scan.nextInt())
  - you can call other methods of class X
    - we haven't seen this so far (comes later)
    - has slightly different syntax

Constructors

- When we create an object from a class the first thing we need to do is initialize all the member variables (the variables defined within the object).
- The constructor is the method used to do this.
- Constructors are optional. If not present then the member variables need to get initialized somewhere else.
- You can identify the constructor because is has no return type (not even `void`) and it has the same name as the class.
- Its parameters and code body behave in the same way as regular methods.
- Constructors are only invoked when you initially create the object.

Client.java

```
public class Client
{
   private double balChecking;       //member variables
   private double balSavings;

   public Client (double checkingBalance, double savingsBalance){
      balChecking = checkingBalance;
      balSavings = savingsBalance;
   }

   public boolean withdrawalChecking (double amount) {
      if (amount < 0 || balChecking < amount)
      {
         System.out.println("Incorrect amount");
         return false;
      }
      else
      {
         balChecking -= amount;
         return true;
      }
   }
   public boolean withdrawalSavings (double amount) {
      // similar to withdrawalChecking
   }
```


Client.java

```
   public double depositChecking(double amount) {
     balChecking += amount;
     return balChecking;
   }

   public double depositSavings(double amount) {} // similar to depositChecking

   public void transfer (char fromAccount, double amount) {
      switch(fromAccount) {
       case 'c':
          balChecking -= amount;
          balSavings += amount;
          break;
        case 's':
          balSavings -= amount;
          balChecking += amount;
          break;
         default:
            System.out.println("Incorrect input to transfer");
      }
   }

   public double balanceChecking () {
      return balChecking;
   }

   public double balanceSavings () {
      return balSavings;
   }
}
```


Bank.java

```
public class Bank {
  public static void main (String[] args) {
   Client c1 = new Client(100,0);
   Client c2 = new Client(0,0);
   double amount;

   amount = c1.depositChecking(100);
   System.out.println("c1's checking is now: " + amount);
   c1.transfer('c',50);

   if (c2.withdrawalSavings(20))
         System.out.println("Withdrawal successful");
   else
         System.out.println("Withdrawal not successful");

   System.out.println ("checking 1: " + c1.balanceChecking());
   System.out.println ("checking 1: " + c1.balanceSavings());
   System.out.println ("checking 2: " + c2.balanceChecking());
   System.out.println ("checking 2: " + c2.balanceSavings());
  }
}
```

The Client Class

- Once the `Client` class has been defined, we can use it again in other programs as needed
- For instance, we have used it in the `Bank` program.
- However, the `Bank` program has not used all methods provided by the `Client` class
- A program will not necessarily use every service provided by an object

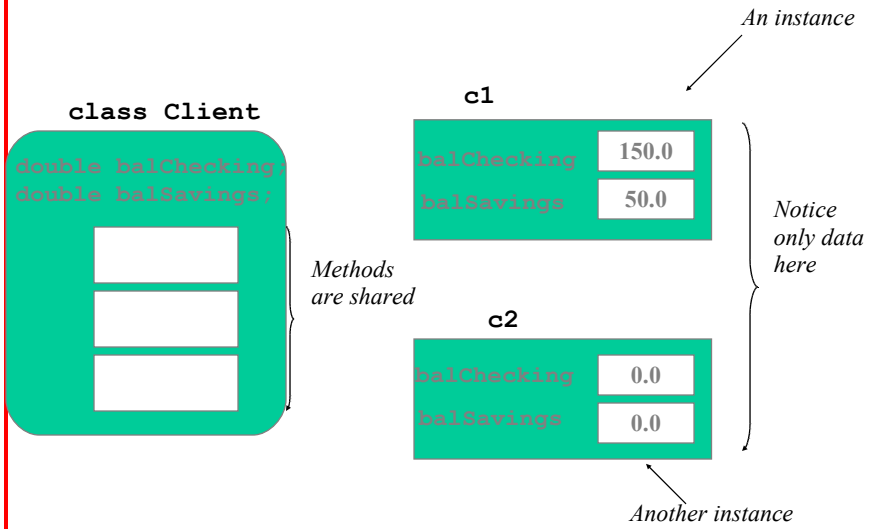
Part 2

Some Object Details

Instance Variables

- The `balChecking` and `balSavings` variables in the `Client` class are called *instance variables* because each instance (object) of the `Client` class has its own values for these variables
- A class declares the type of the data, but it does not reserve any memory space for it
- Every time a `Client` object is created, a new `balChecking` variable and a new `balSavings` variable is created as well
- The objects of a class share the method definitions, but they have unique data space for their instance variables
  - This allows two objects to have separate states

Instance Data



Method Declarations Revisited

- A method declaration begins with a *method header*

```
public char calc (int num1, int num2, String message)
```

modi-fier | return type | method name | parameter list

- The parameter list specifies the type and name of each parameter
  - names can be freely chosen (similar to variable names)
- The names of parameters in the header are called *formal parameters*
- Formal parameters can be used in the method body in the same way variables are used

Method Declarations

- The method header is followed by the *method body*

```
char calc (int num1, int num2, String message)
{
    int sum = num1 + num2;
    char result = message.charAt (sum);

    return result;
}
```

sum and result are *local data*

The return expression must be consistent with the return type

Local Data

- A method can declare its own variables
- These variables are local to the method
- Local variables are created (memory allocated) each time the method is called and discarded when the method finishes execution
- This is different to member variables
  - Member variables are declared in the class but not inside any particular method
  - Member variables exist throughout the lifetime of an object

The return Statement

- The *return type* of a method indicates the type of value that the method sends back to the calling location
- A method that does not return a value has a `void` return type
- The *return statement* specifies the value that will be returned
- Its expression must conform to the return type

Example

```
public class Calc {
…
 int add(int x, int y) {
   int sum = x + y;
   return sum;
 }
}

 public static void main(String args[])
 {
   int result;
   Calc mycalc = new Calc();
   result = mycalc.add(5,2);
 }
```

Describe the flow and result

What would happen if the type was not int?

Parameters

- Each time a method is called, the *actual parameters* in the invocation are copied into the *formal parameters*

```
ch = obj.calc (2, count, "Hello");
```

```
char calc (int num1, int num2, String message)
{
   int sum = num1 + num2;
   char result = message.charAt (sum);

   return result;
}
```


Constructors Revisited

- Recall that a constructor is a special method that is used to set up a newly created object
- When writing a constructor, remember that:
  - it has the same name as the class
  - it does not return a value
  - it has no return type, not even `void`
  - it often sets the initial values of instance variables
- The programmer does not have to define a constructor for a class

Examples for Client

```
public Client (double startChecking, double startSavings) {
      balChecking = startChecking;
      balSavings = startSavings;
}


public Client () {
   checking = 0;
   saving = 0;
}
```

Private and Public

- In our example, we declared
  - member variables as `private`
  - Member methods as `public`
- In general, each member (variable, method) can be either declared `private` or `public`
- `public`
  - the member can be accessed externally (from outside the object) using the DOT operator
- `private`
  - the member cannot be accessed externally. Only during execution within the object can the member be accessed.

Accessing an instance Variable

- Assume `Client` declares its instance variables public

```
public double balChecking;    //member variables
public double balSavings;
```

- Assume the `Bank` has created a client

```
Client c1 = new Client(0,0);
```

- There are two options to access the instance variables of c1:

```
double balance = c1.balChecking;
vs.
double balance = c1.balanceChecking();
```

  - In the first case, the `balChecking` variable is directly accessed via the DOT operator
  - In the second case, a *getter or accessor* method of the Client is called that returns the value of the variable

Modifying an Instance Variable

- There are two options to modify the data of the c1:

```
c1.balChecking = 100;
vs.
c1.depositChecking(100);
```

  - In the first case, the `balChecking` variable is directly modified. It is accessed via the DOT operator and a value is assigned to it.
  - In the second case, a *setter or mutator* method of the Client object is called that performs the modification

Encapsulation

- Most instance data should only be accessed via getter and setter methods
  - Guarantees data is only accessed through one way: easy to control
- In order to protect against direct access,
  - instance variables should be declared `private`
  - all access and modifications to variables should be done via getter and setter methods
- Constants might or might not be made public depending on the application
- For instance, assume that each deposit and withdrawal is associated with a fee
  - we want to make sure that each modification of the balance includes the fees

Considering Fees

```
public class Client
{
   private double balChecking;     //member variables
   private double balSavings;

   public final double FEE = 1.5;

   …

   public boolean withdrawalChecking (double amount) {
      if (amount < 0 || checking < amount)
      {
         System.out.println("Incorrect amount");
         return false;
      }
      else
      {
         balChecking -= amount + FEE;
         return true;
      }
   }

   public double depositChecking (double amount) {
     checking += amount - FEE;
   }
```


Private vs. Public Methods

- We declare methods that should be publicly accessible as `public`
  - they are the services
  - they are the *interface* with which objects of the class can be accessed and manipulated
- We might have some helper methods used for internal decomposition
  - they support other methods in the class
  - they should be declared `private`

Classes with and without Main

- So far, we have seen two types of classes
  - classes that contain
    - a main method, no instance data, no other methods
    - examples: bank, calculator, and nearly all classes we programmed so far
  - classes that contain
    - no main method, a set of other methods, maybe some instance data
    - examples: Client, Scanner and other library classes

Classes with `main`

- These are classes that typically start an application
- `main` is declared `static` and returns `void`
  - Also has a special input argument
  - The keyword static indicates that the method is a class method
  - It can be called without the requirement to instantiate an object of the class.
  - (Other methods can be static, too. For example the methods in the `Math` class)
- When we start a program (run in DrJava), the interpreter invokes the `main` method of the class.
- A class X that does not contain a `main` method cannot execute on its own. We need at least one class with a `main` in our application

Application

- In theory, each application could be written as one big Java class.
- However, it is better to split an application into different classes that handle different tasks or sub-concepts of the application.
- In this case a "starter" class with a `main` method starts the application, creates objects of other classes, and coordinates the execution of the application

Pretty Printing

- A class often contains a method that provides a string representation of its variables
- In Class Client

```
public String toString()
  {
    String check = "Balance Checking: " +
                   balChecking + "\n";
    String save = "Balance Saving: " +
                   balSavings + "\n”;
    return(check+save);
  }
```

- In Class Bank

```
System.out.println(c1.toString());
```


A funny example

- A cat class
  - a cat can be fed
  - feeding leads to mood swings
- A starter class
  - creates cats
  - feeds cats and observes behaviour

Cat.java

```
public class Cat {
   private float weight;
   private int age; private boolean isFriendly;

   public Cat() {
      weight = 3.8f;
      age = 2;
      moodSwing();
   }
   public String toString(){
      String sWeight = "I weigh " + weight + " kg.\n";
      String sAge = "I'm " + age + " years old.\n";
      String sFriendly = (isFriendly)? "I'm the nicest cat in the world"
                                     : "One more step and I'll attack.";
      return (sWeight+sAge+sFriendly);
   }
   public float feed(float food){
      weight += food;
      System.out.println("it wasn't Fancy Feast's seafood fillet...");
      wail();
      return weight;
   }
   private void wail() {
      System.out.println("Miiiiaaawwwwwww!");
      moodSwing();
   }
   private void moodSwing(){isFriendly = ((int)(Math.random()*2) == 0);  }
}
```

How does this work?

How does this work?

FeedTheCats.java

```
public class FeedTheCats
{
   public static void main(String args[])
   {
       Cat Frisky = new Cat();
       Cat Tiger = new Cat();

       System.out.println("Frisky: " + Frisky.toString());
       System.out.println("Tiger: " + Tiger.toString());
       System.out.println("We are about to feed the cats...");
       float newWeight = Frisky.feed(1.2f);
       System.out.println("Frisky should weigh " + newWeight + " kg.");
       newWeight = Tiger.feed(2.4f);
       System.out.println("Tiger should weigh " + newWeight + " kg.");

       System.out.println("Frisky: " + Frisky.toString());
       System.out.println("Tiger: " + Tiger.toString());
   }
}
```


Method invocation within object

- Note:
  - If a class or an object calls a method on another object referenced by a variable name, the call is
    - Variablename.methodname
  - If an object calls a method on itself, only the method name needs to be written:
    - wail();

Two ways to implement Calculator

1. Application style
   - Calculator class
     - with methods for addition/division
     - no main method
   - Starter class
     - with main
     - creates a calculator object and uses it (the for loop in original calculator)
- Calculator class with object
  - methods for addition/division
  - `main` method
    - Creates an object of itself
    - Has loop to ask input and redirect to other methods

Using Objects

- Sometimes an object has to interact with other objects of the same type
- For example, we might add two `Rational` number objects together as follows:

```
r3 = r1.add(r2);
```

- One object (`r1`) is executing the method and another (`r2`) is passed as a parameter

Rational Numbers Are…

$$\frac{5}{10} = \frac{1}{2}$$

RationalNumbers.java

```
public class RationalNumbers{
   public static void main (String[] args) {
      Rational r1 = new Rational (6, 8);
      Rational r2 = new Rational (1, 3);

      System.out.println ("First rational number: " + r1);
      System.out.println ("Second rational number: " + r2);

      if (r1.equals(r2))System.out.println ("r1 and r2 are equal.");
      else System.out.println ("r1 and r2 are NOT equal.");

      Rational r3 = r1.add(r2);
      Rational r4 = r1.subtract(r2);
      Rational r5 = r1.multiply(r2);
      Rational r6 = r1.divide(r2);

      System.out.println ("r1 + r2: " + r3);
      System.out.println ("r1 - r2: " + r4);
      System.out.println ("r1 * r2: " + r5);
      System.out.println ("r1 / r2: " + r6);
   }
}
```

What are we doing here?

What does this mean?

What is going on here?

Questions

- RationalNumbers.java used a class called Rational:
  - What do you think the member variables should be in order to represent rational numbers?
  - How would you write the constructor?
  - Assuming that the denominator is the same, how would you write the ADD method?
  - If the denominator was not the same, how would you write the ADD method?
  - Assuming the denominator is the same, how would you write the equal method?

Part 3

Thinking Like A Programmer

Why Objects?

- Manageability
  - Self-contained (all in a single class)
  - Shareable (import .class)
  - Security features (private, protected, public)
- Lifelike:
  - Maps to real-life entities

Manageability

- Programs tend to get very long, hard to debug and difficult to solve in one sitting
- The way to control this is to write small programs
- Large programs can be reduced to many little methods that are easy to debug… this is called *method decomposition*.

Method Decomposition

- A method should be relatively small, so that it can be readily understood as a single entity
- A potentially large method should be decomposed into several smaller methods as needed for clarity
- Therefore, a service method of an object may call one or more support methods to accomplish its goal

Let's see an example…

PigLatin.java

```
public class PigLatin {
   public static void main (String[] args) {
      String sentence, result, another;
      Scanner scan = new Scanner(System.in);

      do {
        System.out.println ();
        System.out.println ("Enter a sentence (no punctuation):");
        sentence = scan.nextLine();

        result = PigLatinTranslator.translate (sentence);
        System.out.println ("That sentence in Pig Latin is:");
        System.out.println (result);

        System.out.print ("Translate another sentence (y/n)? ");
        another = scan.nextLine();
      }
      while (another.equalsIgnoreCase("y"));
   }
}
```

A potentially large program

What does this do?

PigLatinTranslator.java

```
public class PigLatinTranslator
{
   //-----------------------------------------------------------
   //  Translates a sentence of words into Pig Latin.
   //-----------------------------------------------------------
   public static String translate (String sentence)
   {
      String result = "";

      sentence = sentence.toLowerCase();

      Scanner scan = new Scanner (sentence);

      while (scan.hasNext())
      {
         result += translateWord (scan.next());
         result += " ";
      }

      return result;
   }
```

Built in string method

While still data left in sentence

Translate that word

Take a word out

Notice how all these methods help reduce the problem

Still decomposing…

- Notice that we have only completed a small part of the job
- We still need to program:
  translateWord

translateWord

```
//-----------------------------------------------------------
// Translates one word into Pig Latin. If the word begins with a
// vowel, the suffix "yay" is appended to the word.  Otherwise,
// the first letter or two are moved to the end of the word,
// and "ay" is appended.
//-----------------------------------------------------------
private static String translateWord (String word)
{
   String result = "";

   if (beginsWithVowel(word))
      result = word + "yay";
   else if (beginsWithPrefix(word))
      result = word.substring(2) + word.substring(0,2) + "ay";
   else
      result = word.substring(1) + word.charAt(0) + "ay";

   return result;
}
```

Notice we are still putting off work until later … decomposition

Using built-in methods to help us

And Finally

```
   private static boolean beginsWithVowel (String word) {
      String vowels = "aeiou";
      char letter = word.charAt(0);
      return (vowels.indexOf(letter) != -1);
   }

   private static boolean beginsWithPrefix (String str) {
      return ( str.startsWith ("bl") || str.startsWith ("pl") ||
               str.startsWith ("br") || str.startsWith ("pr") ||
               str.startsWith ("ch") || str.startsWith ("sh") ||
               str.startsWith ("cl") || str.startsWith ("sl") ||
               str.startsWith ("cr") || str.startsWith ("sp") ||
               str.startsWith ("dr") || str.startsWith ("sr") ||
               str.startsWith ("fl") || str.startsWith ("st") ||
               str.startsWith ("fr") || str.startsWith ("th") ||
               str.startsWith ("gl") || str.startsWith ("tr") ||
               str.startsWith ("gr") || str.startsWith ("wh") ||
               str.startsWith ("kl") || str.startsWith ("wr") ||
               str.startsWith ("ph") );
   }
}
```

Describe what is going on here

When thinking about your problem…

- First: Think of the problem as a whole or think of it as you would solve it by hand without a computer
- Then: Try to divide the work you did into steps or parts
  - Each of these steps or parts could be a potential little program contained in a method
- Last: Think of the parameters and return values for these steps or parts

If more time, give problems to solve during class time