Chapter 8

Object Communication

Lecture slides for:

Java Actually: A Comprehensive Primer in Programming

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Overview

- Responsibilities and roles
- Defining good abstractions
- Structured programming
- Redundant code
- Communication and cooperation
- Associations
- Ownership
- Encapsulation
- Class design
- Method overloading
- Documenting source code
- Example: CD-collection
- Generating documentation (`javadoc`)

Responsibilities and Roles

- The properties and operations defined in a class determine:
  - Which abstraction the class represents.
  - The responsibility domain of the class
  - What roles objects of the class fulfill.
  - Which program code ought to part of the class.
- Advantages of good abstractions
  - Easy to understand the program
  - Easy to modify the program
  - Can reduce the size of the program
  - Easy to identify and remember what the different parts of the program do.
  - Promote reuse of code
- Usefulness of good abstractions becomes clear as the size of the program increases.

Creating good abstractions

- What is a good abstraction?
- A good abstraction:
  - Binds properties and operations that belong together
  - Makes it possible to avoids duplication of code
  - Limits the scope of future changes
  - Makes it easy to understand the program:
    - Gives classes and objects easily understandable responsibilities and roles
    - Hides details that not necessary for the overall understanding of the abstraction
- Determine which methods will be useful to have in order to manipulate the fields of a class.
- Remove and hide methods and fields which are not directly useful in a class.
- Do not lump together many responsibilities. Let the role of each object be as clear as possible.
- Abstraction to represent an object often comes before its *implementation*.
- The implementation process can provide insights and ideas about new abstractions that can be useful.

Programming methodology: *structured programming*

- *Behaviour* of objects is realized by applying *structured programming*.
- Actions in a method are described by the following *control structures* only:
  - Sequence (block)
  - Choice (conditional execution)
  - Repetition (loops)
- Results in methods that are simpler
  - to understand,
  - to test and debug,
  - to modify and maintain.

Duplicate program code

- Makes program maintenance difficult.
- Same modifications must be done in several places in the code.
- Implies that program code should be restructured.

Example:

```
> java Report1
import java.util.Scanner;
public class Report1 {
  public static void main(String[] args) {
    Scanner keyboard = new Scanner(System.in);
    System.out.print("Number of cars: ");
    int NumOfCars = keyboard.nextInt();
    System.out.print("Number of boats: ");
    int NumOfBoats = keyboard.nextInt();
    System.out.print("Number of trains: ");
    int NumOfTrains = keyboard.nextInt();
    System.out.print("Number of motor cycles: ");
    int NumOfMotorCycles = keyboard.nextInt();

    System.out.print(NumOfCars);
```

```
    if (NumOfCars == 1) {
      System.out.print(" car, ");
    } else {
      System.out.print(" cars, ");
    }

    System.out.print(NumOfBoats);
    if (NumOfBoats == 1) {
      System.out.print(" boat, ");
    } else {
      System.out.print(" boats, ");
    }

    System.out.print(NumOfTrains);
    System.out.print(" train and ");

    System.out.print(NumOfMotorCycles);
    if (NumOfMotorCycles == 1) {
      System.out.println(" motor cycle.");
    } else {
      System.out.println(" motor cycles.");
    }
  }
```



```
}
```

- Total: 38 LOC (Lines Of Code).
- Each new transport type will require approximately 8 new lines and impacts 3 old lines.
- If the prompt is changed, e.g. "How many cars?", then this change must be done for several other lines.
- Easy to make a mistake. For example, copying the code for *motor cycles* to handle *buses*, and forgetting to update the conditional expression.

```
System.out.print(numOfBuses);
if (numOfMotorCycles == 1) {
    System.out.println(" bus.");
} else {
    System.out.println(" buses.");
}
```

- How to avoid code duplication:
  – Use loops
  – Extract common behavior into methods
  – Use arrays instead of handling each value separately.

Code with less duplication and better abstraction

- Introduce a new abstraction to simplify the code: `NumberOFTimes`.

```
import java.util.Scanner;
class NumberOfTimes {
  String singular, plural;
  int numOfTimes;

  NumberOfTimes(String singular, String plural) {
    this.singular   = singular;
    this.plural     = plural;
    Scanner keyboard = new Scanner(System.in);
    System.out.print("Number of times " + plural + ": ");
    numOfTimes = keyboard.nextInt();
  }
  void print() {
    if (numOfTimes == 1) {
      System.out.print("1 " + singular);
    } else {
      System.out.print(numOfTimes + " " + plural);
    }
  }
}
```



```
// Client that uses NumberOfTimes class.
public class Report2 {
  public static void main(String[] args) {
    NumberOfTimes[] items = { new NumberOfTimes("car", "cars"),
        new NumberOfTimes("boat", "boats"), new NumberOfTimes("train", "trains"),
        new NumberOfTimes("motor cycle", "motor cycles") };

    for (int i=0; i < items.length; ++i) {
      items[i].print();
      int remaining = items.length - 1 - i;
      switch (remaining) {
        case 1:  System.out.print(" and "); break;
        case 0:  System.out.println(".");  break;
        default: System.out.print(", ");
}}}}
```

- Total: 30 LOC
- Exactly same behaviour, and to introduce a new type costs hardly one line of code and has no impact on the existing code.
- To introduce a new prompt only requires to replace one line of code in the `NumberOfTimes` class:

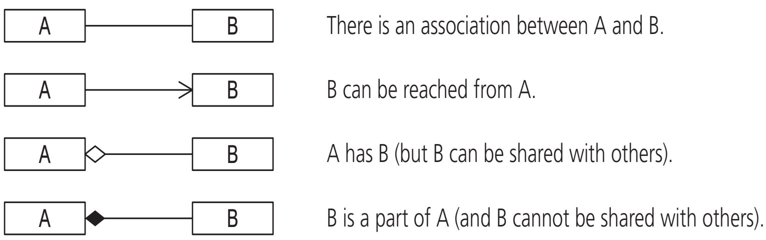
```
System.out.print("How many " + plural + "? ");
```

Communication and cooperation

- Method calls in Java are used to:
  - Make objects cooperate
  - Query objects about information
  - Give information to other objects
  - Delegate work to other objects
  - Move information among objects using parameters and return values.

- In order to call a method on an object, we need a reference to the object.
- How to obtain a reference to an object:
  - Create a new object with the new operator. This is not particularly useful if you want to refer to an existing object.
  - Ask another object for a reference.
  - Store the reference in a local variable. The reference is not accessible once the method finishes executing.
  - Store the reference in a field variable. This creates a long-lasting association between the object who has the field and the object that the field refers to.

Associations: UML notation



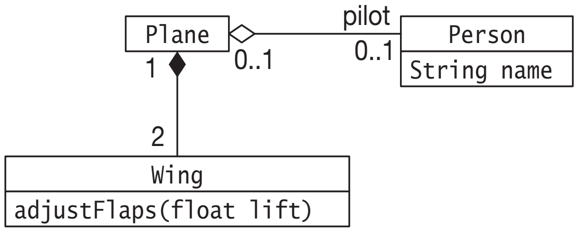
Multiplicity	Description
1	Only one object can fulfil the association. A `Wing` object is attached to exactly one `Plane` object.
0..1	Zero or one object can fulfil the association. A `Plane` object has 0 or 1 `Person` object that is a pilot.
0..*	Any number of objects can fulfil the association.
n	Only *n* objects can fulfil the association, where $n > 1$. A `Plane` object has exactly 2 `Wing` objects.
0..*n*	Up to and including *n* objects can fulfil the association, where $n > 1$. A `Plan` object can carry zero or maximum *n* `Person` objects that are passengers.

Example of Relationships

```
class Person {
  String name;
  // ...
}

class Wing {
  void adjustFlaps(float lift) {
    //...
  }
  // ...
}

class Plane {
  Wing leftWing;
  Wing rightWing;
  Person pilot;
  // ...
}
```

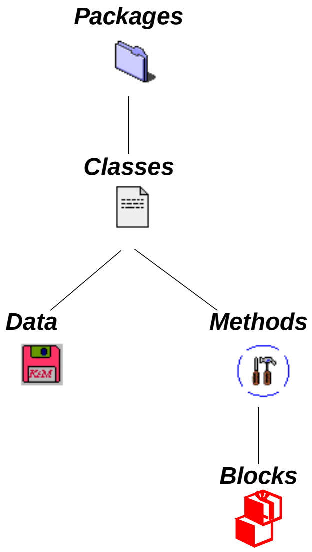


- A plane has (owns) two wings.
- A wing is attached to a plane.
- A plane has one person (at a time) who is the pilot.
- A person can be a pilot of a plane (at a time).

Object Ownership

- Owner of a object has often / usually:
  - a field variable with a reference value that refers to the object it owns.
  - the main responsibility to maintain a reference to the object.
  - control over the life time of the object.

Encapsulation



- *Abstraction* focuses on the *visible behaviour* of an object, while *encapsulation* focuses on *hiding* the *implementation* that offers this behavior.

  A class has 2 *views*:

  – *Contract* that corresponds to our abstraction of the behaviour that is common for all objects of the class.
    - Consists of names of methods and documentation on how *clients* (i.e. other objects) can use objects of the class, and how each method ought to be used.
    - Purpose: allows objects to communicate with each other.

  – *Implementation* corresponds to *representation* of the abstraction and *mechanisms* that provide the desired behavior.
    - Consists of field variables and Java statements that provided the behaviour when executed.

Hiding Information

- *Encapsulation* leads to separation of *contract* and *implementation*.
  – Objects as *black boxes* where the implementation is hidden.
    Contract:
    - **What** a class offers - clients use the behavior of the class.

    Implementation:
    - **How** a class implements its behavior, not a concern of the client.

- Hiding in Java:
  – Classes can be hidden.
  – Individual fields and methods in a class can be hidden.
  – Access modifiers can be used in the declaration to specify encapsulation.

Modifier	Meaning
`public`	Class, field or method is accessible everywhere
`private`	Fields and methods are only accessible to the code in the class in which they are declared. Classes that are "top-level" cannot be private.

Data Abstraction: *Hiding information*

- Hide implementation details of a class:
  - Use access modifiers to hide fields and methods.
  - Allows changes in the class implementation with minimal impact on clients.
  - Leads to fewer dependencies between classes.
  - Increases reuse of code.
  - Results in program parts that are *black boxes*.

Class Design

- Use *standard* format for class declarations.
- A class with to many properties or too many responsibilities / behavior should be split into several classes.
- Use meaningful names for classes and methods that reflect their purpose.
- Field variables:
  - Usually declared private.
  - Ought to be initialized in a constructor.
  - Not always necessary with *selector* / *mutator* methods.
- Always initialize local variables of a method.
- Avoid too many primitive data types in a class. It is a sign to rethink their purpose.

Method Overloading

- *Signature* of a method consists of its *name* and *formal parameter list*.
- Which method is executed depends on, among other things, its signature.
- When a method is called, there must be a method with a signature that matches the signature of the call. For overloaded methods, this is determined at compile time.
- Constructor overloading is also a form of method overloading.
- Changing the return value *alone* is *not* sufficient to overload a method.

```
class Light {
    private int numOfWatts;
    public double cost(int numOfHours) {
        double KWH_price = 0.35; // cents pr. kiloWatt hour
        double price = ((double)numOfWatts * numOfHours/ 1000)* KWH_price;
        return price;
    }
    public double cost(int numOfHours, double KWH_price) {
        double price = ((double)numOfWatts * numOfHours/ 1000)* KWH_price;
        return price;
    }
}
```

signature

Documenting the source code

- Main goal: A program should be easy to read and understand.
- What is important to document:
  - This is not always obvious.
  - Methods: what they do is more important than how they are implemented.
  - Fields: what is their purpose
  - Classes:
    - What abstraction the class represents and what responsibilities it has.
    - What role the objects of the class fulfill and what their typical usage.
  - Algorithms that are used (pseudo kode)
  - Overall description of how the different parts of the program fit together.
- How much documentation is enough?
  - The bigger and more complex a program, the more important the need for good documentation.
  - Choosing meaningful names and writing code that is easy to understand decreases the need for documentation.
  - Documentation should be useful. i.e. have a purpose.

Which method is easy to understand?

```
// Compute the average of numbers in an array.
public class Average {
  /** This method calculates the average by traversing over the array. */
  static double compute(double[] array) {
    double value = 0;
    for (int index = 0; index < array.length; ++index) {
      value += array[index];  // Add the current value from the array
    }
    return value/array.length;
  }
  static double average(double[] values) {
    double sum = 0;
    int numOfValues = values.length;
    for (int i = 0; i < numOfValues; ++i) {
      sum += values[i];
    }
    return sum/numOfValues;
  }
  public static void main(String[] args) {
    double[] values = { 1.0, 3.2, 4.1, 7.8, 9.3, 11.4, 8.5 };
    System.out.println(compute(values));
    System.out.println(average(values));
  }
}
```


Javadoc comments

```
/** This is a javadoc comment. */
```

- Javadoc comments in the source code can be used by the `javadoc` tool to generate documentation.
- Information provided using *markup tags* in Javadoc comments is extracted by the `javadoc` tool to generate the documentation.
- Javadoc comments can be used to document:
  - Classes
  - Fields
  - Methods

Markup Tags	Purpose
`@param` *<parameterName> <description>*	Description of a formal parameter of a method.
`@return` *<description>*	Description of the return value from a method.

Example: CD Collection

- Using several classes.
- Using constructors.
- Creating objects, including arrays.
- Calling methods.
- Using access modifiers.
- Using `javadoc`.

CD Collection (cont.)

```
/**
 * Administration of a CD collection.
 * Uses objects of the classes CDCollection and CD.
 */
public class CDAdmin {
  public static void main (String[] args) {
    CDCollection music = new CDCollection(4);
    music.printCDCollection();

    music.insertCD (new CD(115.50, 4));
    music.insertCD (new CD(200,12));
    music.insertCD (new CD(99.99, 5));

    music.printCDCollection();

    music.insertCD (new CD(150.99, 12));
    music.insertCD (new CD(123.50, 15));

    music.printCDCollection();
  }
}
```

```java
/** This class represents a collection of CDs. */
public class CDCollection {
  /** Index of the last CD inserted. */
  private int indexOfLastCD;
  /** Array that holds the CDs. */
  private CD[] CDArray;
  /** Create a CD collections.
   *  @param maxNumOfCDs Maximum number of CDs that can be stored in the
   *                     collection. */
  public CDCollection (int maxNumOfCDs) {
    indexOfLastCD = -1;
    CDArray = new CD[maxNumOfCDs];
  }
  /** Insert a CD.
   *  @param newCD CD to be inserted.
   */
  public void insertCD (CD newCD) {
    if (!isFull()) {
      ++indexOfLastCD;
      CDArray[indexOfLastCD] = newCD;
      System.out.println ("New CD inserted.");
    } else {
      System.out.println ("Collection is full.");
    }
  }
```



```java
  /** @return Number of CDs in the collection at the moment. */
  public int getNumOfCDs() { return (indexOfLastCD +1); }

  /** @return true if the collection is full. */
  public boolean isFull() { return getNumOfCDs() >= CDArray.length; }

  /** @return true if the collection is empty. */
  public boolean isEmpty() { return (getNumOfCDs() <= 0); }

  /** Print information about the collection. */
  public void printCDCollection() {
    System.out.println("******************************");
    System.out.println("Number of CDs: " + getNumOfCDs());
    System.out.printf("Value of collection: £ %.2f%n",
                      totalValueOfCollection());
    System.out.printf("Average value of a CD: £ %.2f%n",
                       averageValueOfCD());
    System.out.println("******************************");
  }
```

```
  /** @return Total value of the CDs in the collection. */
  public double totalValueOfCollection () {
    if (isEmpty()) return 0.0;
    double totalValue = 0.0;
    for (int i = 0; i <= indexOfLastCD; i++) {
      totalValue += CDArray[i].getPrice();
    }
    return totalValue;
  }

  /** @return Average price of a CD. */
  public double averageValueOfCD () {
    if (isEmpty()) return 0.0;
    return totalValueOfCollection() / getNumOfCDs();
  }
}  // End of CDCollection
```



```
/** This class represents a CD. */
public class CD {

  /** Price of the CD. */
  private double CDPrice;
  /** Number of tracks on the CD. */
  private int numOfTracks;

  /** Create a CD.
   *  @param price Price of the CD.
   *  @param tracks Number of tracks on the CD.
   */
  public CD(double price, int tracks) {
    CDPrice = price;
    numOfTracks = tracks;
  }

  /** @return Price of the CD. */
  public double getPrice() { return CDPrice;}
  /** @return Number of tracks on the CD. */
  public int getNumOfTracks() { return numOfTracks;}
}
```

Output from the program:

```
******************************
Number of CDs: 0
Value of collection: £ 0.00
Average value of a CD: £ 0.00
******************************
New CD inserted.
New CD inserted.
New CD inserted.
******************************
Number of CDs: 3
Value of collection: £ 415.49
Average value of a CD: £ 138.50
******************************
New CD inserted.
Collection is full.
******************************
Number of CDs: 4
Value of collection: £ 566.48
Average value of a CD: £ 141.62
******************************
```


Javadoc

```
1. javadoc          <names of Java files>
2. javadoc -private <names of Java files>
```

1. Generate documentation for `public`, `package` and `protected` declarations (classes, interfaces, methods, fields).
2. Generate documentation for *all* declarations (classes, interfaces, methods, fields).

- Example of usage:

```
javadoc CD.java CDCollection.java CDAdmin.java
javadoc *.java
javadoc -private *.java
```

Generated documentation (`javadoc`)

Field Summary	
private CD[]	CDArray Array that holds the CDs.
private int	indexOfLastCD Index of the last Cd inserted.

Constructor Summary
CDCollection(int maxNumOfCDs) Create a CD collections.

Method Summary	
double	averageValueOfCD()
int	getNumOfCDs()
void	insertCD(CD newCD) Insert a CD.
boolean	isEmpty()
boolean	isFull()
void	printCDCollection() Print information about the collection.
double	totalValueOfCollection()

Experience

- Ability to create good abstractions, write good code and document the source code correctly comes with experience.
- Ways to gain experience:
  - Write source code.
  - Compile code and find errors.
  - Read code other people have written.
  - Experiment with existing code.
  - Maintain code over a long period.
- Experience helps you to appreciate good code that is properly documented.
- As always: *Practice makes perfect*.