COMP 303 Study guide

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Part I
Introduction

1 Disclaimer

These notes are curated from Professor Joseph Vybihal's COMP303 lectures at McGill University. They are for study purposes only. They are not to be used for monetary gain.

2 About This Guide

I make my notes freely available for other students as a way to stay accountable for taking good notes. If you spot anything incorrect or unclear, don't hesitate to contact me via Facebook or e-mail at `http://francispiche.ca/contact/`

Part II
Writing Good Code

Good code is:

- Optimal (Time complexity and memory)
- Simple
- Correct
- Robust (Few crashes, good error handling etc.)
- Easy to read
- Is well documented
- Uses accepted engineering techniques.

3 Strategies for Writing Good Code

3.1 Optimality

To minimize memory usage we could:

- Encode long strings of data (compressing)
- Re-calulate instead of store values (trade-off with speed)
- Check library overhead!

- Data structure overhead (graph has a lot more pointers than a linked list!)

To minimize time complexity:

- Come up with a better algorithm (Improve big O)
- Store more things in RAM (rather than in a DB or over a network)
- Avoid nesting of pointers
- Avoid deep or unnecessary recursion

3.2 Simplicity

Strategies for simplicity:

- Good variable names (avoid single letters except for array index's)
- Don't use lots of variables when an array is more appropriate
- Use simpler data structures if possible
- Reduce the volume of code
- Limit line length
- Modularize the program
- Use algorithms that are well known if possible

3.3 Correctness

The only way to be somewhat sure that your program is correct is through rigorous testing. Some things are easier to test than others, and theres entire QA departments that specialize in testing. But with the rise of Agile, more and more standard Devs need to be good at testing.

Some general ideas on testing:

- 1 test per 1 function
- Test valid inputs
- Test invalid inputs
- Test edge cases
- Validate that the output is correct

There's a ton of material online about testing and I definitely recommend taking some time to learn about more in-depth testing methods than what is covered in this course. It's required in almost all dev jobs and it's a very valuable skill to have.

3.4 Readability

This comes from good indentation, spacing and general style of code. Most people know this implicitly so I won't go into detail. For examples see the lecture slides from Lecture 2.

3.5 Comments as documentation

The first place documentation happens is on the code level. This is where you can remove any ambiguity or sources of confusion from your code for other developers (or even future you). While real projects require real documentation, and excessive comments can be a detriment to readability, more comments are generally better than not enough. Break down your complex algorithms into comment separated steps, or add side-notes on anything that could be confusing to another developer.

4 Well Designed Objects

A well designed object should be one that does not cause any "wut?" moments amongst a team of developers. Specifically:

- Single class per file
- Single purpose
- Expose only essential information
- Support an API structure
- Follow appropriate inheritance methods

4.1 Single Purpose

A class should be used to represent an idea, concept or object (pun-intended), and nothing more. A student should only contain ideas directly relevant to a student. A `Car` class should not have information about busses or trucks.

This ensures that someone using your class can quickly find out everything there is to know about your object in an intuitive way. If your Student class has information about apples buried inside somewhere, someone on your team would have a hard time finding that out.

4.2 Restriction of Information

This is done to ensure that the class will be used correctly. There should be a decent amount of thought put into which parts of the code are "internal" and "external" to the class, ie: what parts of the class does the program need easy access to?

Any time you use the `public` keyword, you should be thinking twice about if it's truly needed.

4.3 Encapsulation

When you take the concepts of single purpose and restriction of information and put them together, you get *encapsulation*. Essentially what this means is that your class should be it's own complete bubble. No code outside the class should do the same things as inside your class, nor should things outside affect the class in an uncontrolled way.

4.4 Inheritance

To avoid duplication of code, we use inheritance to relate objects. This way classes can share common elements and simplify our lives. For details on inheritance see my COMP250 guide.

Note that private information from a parent is not visible t the child.

To design inheritance well:

- A parent is more general
- A child is more specific

4.5 Pre & Post Conditions

To keep things coherent, if a parent object imposes a condition on data, the child should maintain this condition. For example if a parent object has the condition that `salary` $>$ `0` then the child should not violate this by overriding the condition with say, negative values. It could, however, override it with `salary` $>$ `10000`.

This is known as a **rich** starting point. Another example of a rich starting point is using a library, or some sample code.

THis might be an issue since you may be inheriting, importing or implementing more features than are really needed.

4.6 Extending vs Wrapping vs Interfaces

Extending is when a new class contains the parent but adds extra methods and variables. Allows for polymorphism (see 250 guide for more on that).

Interfaces are used when the classes implementing are not necessarily related, but share common methods. For example the `Iterable` interface can be implemented by say, a `Degree` class, which contains a list of courses. But also a `Queue` class which has nothing to do with degrees or courses conceptually. So this allows for polymorphism across multiple inheritance trees.

Wrapping is not a formal construct in a language, but it is the idea of placing objects inside a "wrapper" class, to put objects together in a more abstracted way.

A special case is `abstract base classes`. These cannot be instantiated and contain both implemented and non-implemented methods. They provide the inheritance properties of extending, with the templating of interfaces.

5 Object Identity & Lifecycle

All objects have an idenity,(a reference or anonymous) and a lifecycle. Their lifecycle depends on the language and how they are handled (in C/C++ you have to manually free them from memory, vs garbage collection)

5.1 Referenced Obects

This is when an object is created by assigning its instance to a variable. `Object o = new Object()`. In this way, when no variables remain that point to this object, it is garbage collected (in Java) or causes a memory leak (C/C++).

5.2 Anonymous Objects

These are objects without references. For example `fn(new Object())`. It is then assigned a reference in the scope of the function, or in the scope of the Object to which it was passed into. For example if you pass an object into the constructor of another object, if it is then assigned to a variable in the second object, it will die with the object it is inside of.

5.3 Static vs Instance

A static object (or variable) can exist only once. That is, it cannot be instantiated. There can be no direct communication between static and instance structures.

The `C` version of this would be in the two different ways of creating structs. One where you give your struct a name at the end, vs if you instantiate it afterwards.

6 Object Class and Class Class

All objects in Java extend the Object class. I went in-depth with this in my 250 guide, but I'll summarize here.

There are a few important methods that the Object class has.

- `toString()`
- `equals(Object o)`
- `hashCode()`
- `clone()`

6.1 Object.toString()

Automatically called by many functions such as print statements. Overwrite this to change the string representation of your object. By default, it stores the name of the object, and a unique hexedecimal identifier.

6.2 Object.equals()

Since the `==` operator only checks if the addresses are the same (for reference types), using it with reference types often has strange results. It is therefore necessary to override the `Object.equals()` method to specify what it means for two objects to be equal. Are their attributes equal?(This is the default) Etc. Note that the default will not look at nested Objects, so you must specify an equals method for complicated data structures.

6.3 Object.hashCode()

Hash data structures are only as good as their hash function. So if the default for your data type is really bad, so you'd have to implement your own hash function (override the hashCode() method.)

6.4 Object.clone()

The default clone makes a shallow copy by only cloning the references. (The contents of the original can be changed by the clone!!). A deep copy would be making a clone of all references and make them point to actual independent locations. This can be done with the clone() method.

6.5 Type Inquiry

This is the idea of testing what type a variable is. This is done using the `instanceof` operator. For example: `x isinstance Shape`.

However, it does not check if it is exactly that type, it instead checks if `x` is part of the inheritance tree of Shape. We can use this to check if a cast will be successful.

We can check for exact class matching with the `Object.getClass()` method. It returns an Object containing the type information for a class. This object contains the name, and a pointer to the superclass object. (The class object of it's parent).

The Class class has some other useful methods such as `isArray()` and `getComponentType()` which 1) tests if the class is array, and 2) if it is, get the type of the components of the array.

7 Reflection

This is the practice of a program analyzing itself.

The Class class we looked at is useful for reflection.

We also have:

- Class
- Package
- Field
- Method
- Constructor
- Array

Using these, we can get all the features of a class.

```
Class super = Rectangle.class.getSuper();

Class[] interfaces = Rectangle.class.getInterfaces();

Package p = String.class.getPackage();

Field[] fields = Math.class.getDeclaredFields();
for (Field f: fields){
   if(Modifier.isStatic(f.getModifiers()))
}

Contstructor[] constructors = Rectangle.class.getDeclaredConstructors();

for(Constructor c: constructors){
   Class[] params = c.getParameterTypes(); // can be used on methods too!
Method m = PrintStream.class.getDeclaredMethod("println", String.class);
m.invoke(System.out, "Hello, world!"); //invoke is only for public methods
}
```

Note that we might get some errors with `getDeclaredMethod()` namely, `NoSuchMethodException`, `IllegalAccessException` , and `InvocationTargetException`

We can then use the `setAccessible(bool tf)` method on Fields to set the field to be able to modified. We can then use `set()` and `get()` on the fields.

In this example, we'll resize an array:

```
Object newA = Array.newInstance(a.getClass().getComponantType(),
    2*Array.getLength(a) + 1);

System.arraycopy(a, 0, newA, 0, Array.getLength(a));

a = newA;
```

8 Generic Types

A generic type is instantiated when an actual type is substituted for the type-variable.

```
public class ArrayList<E>{
   public E get(int i){...}
}
```

If a type is used, it must always be the same for the same type variable. So if you give `E` a String, all references to `E` must be with a String.

We can take this further, with extending. For example:

```
public static <E, F extends E> void append(ArrayList<E> a, ArrayList<F> c){...}
```

So this would only allow types E and F if F extends E.

Going *even further* we can use wildcards like this:

```
public static <E> void append(ArrayList<? super F> a, ArrayList<F> b, int
    count){...}
```

To say that anything which is a parent of F is valid.

It's worth noting that all this stuff with generics is really just for the compiler and is an abstraction. The hardware doesn't care, and actually once the code is compiled, everything is an Object. Due to this, all Generics are just Objects when you try to do type inspection on them at runtime.

Generics can't:

- Throw or catch generic types.
- Use primitives
- Be static

- Be instantiated
- Mess up inheritance

9 Specifications

A specification is a written document from the designer to the programmer specifying the exact requirements for the project.

They usually include:

- User interface
- Input and Output
- Files and databases
- Objects, data structures, algorithms
- Features/functionality
- Menus, GUI's etc.

They are hard to write. They have to cover all cases, be clear, be what the client wants, and limiting assumptions.

How can we use the compiler to enforce specifications?

9.1 Design by Contracts

An interface can be used as a contract to enforce specifications.

Note that a class can implement multiple interfaces, and an interface can extend another interface.

However this doesn't contain any information about how the methods should be implemented, this is what the document is for.

When we do this, we could have something like `SomeInterface x = new SomeClassThatImplemented()`. The type of the variable dictates which methods can be called. (Methods that are in the class but not the interface cannot be accessed).

10 Anonymous Objects and Classes

As mentioned in a previous section, we can create objects without assigning them to a variable. This is useful for passing it into a method, which forces it to be garbage collected at the end of the method. Or, for passing into the constructor of another object, so that when the new object is destroyed, both will be destroyed.

We can also write an anonymous class directly in the instantiation of an object!

```
Example<Object> ex = new Example<>(){
   public int compare(Example e1, Example e2){
      return e1.compareTo(e2)
   }
}
```

When doing this, the class is tied to exactly one object. When the object is garbage collected, so is the class.

Even crazier, we can make a method, which will generate new anonymous classes!

```
public class Country{
   public static Comparator<Country> comparatorByName(){
      return new Comparator<Country>(){
         public int compare(Country c1, Country c2){
            return c1.getName().compareTo(c2.getName());
         }
      };
   }
}
```

Part III
Aside: Swing GUI Programming

I'll refrain from copy pasting the code from the slides here, but I'll do my best to provide the explanation that Prof. Vybihal gave in class.

11 Basic Structure

The basic element of a GUI in swing as a `JFrame` object. This will cause the window to be displayed, and can be populated with elements.On this you can set a size, set a layout, (there

are layout objects in Swing too, for example `GridLayout`). You can then add a listener to this frame to specify close, resize, minimize behaviors. (By implementing interfaces in an anonymous class).

Next is the `JPanel` object. This is like the window, but is instead a canvas onto which elements are placed. This will be placed within the window. You can also give layouts to a panel,

To add buttons, we need to add listeners to our button elements. This is done by implementing the `actionPerformed` method. This method take an `ActionEvent` object which has information about the event.

12 Object Truth & Writing Good Classes

Classes and objects represent a logical entity, and so must always stay consistent with the context of that entity. Put another way, they are an analogy to real things, and so must be consistent with the analogy. If we have a class Student, we expect it to behave and contain things that a Student would have.

Truth is the idea that the objects instantiated from a class are consistent with the analogy of the class.

If we use setters, getter and mutators, we must ensure that they preserve truth.

A class is**invariant** when all objects of the class are always in a valid state.

This may be broken for a moment in time **during** a "fix" to maintain this valid state.

This idea is similar to that of **cohesion**, in which all methods of a class should belong to the same abstraction or analogy. If the class is for Students, it doesn't have anything else.

We also need to find a balance with convenience, since too much cohesion can make the classes hard to use. For example, `pop()` is not only a pop. It also returns a value, so it's really a `peek()` and a `remove()`.

We should also name and program in a way that is intuitive and consistent.

13 Defensive Programming

Always assume people are going to break your stuff. We must then validate all inputs and outputs.

We do this using a **precondition** and **postcondition**. We use the precondition to test the inputs, do some work assuming everything is fine, and then validate the result at the end. Usually we can just use one, (usually preconditions because it saves work of doing the method).

We throw exceptions when the expectation of the result is not obeyed. (If one of the conditions fails.) We only return if the result and inputs were valid.

Part IV
Tools That Aid Good Design

14 Unit Testing

A unit is a single "functioning unit", that is, it has no specific size or shape. It could be one method, a class, or collection of classes. We then cover this unit by handling all possible cases.

We've already covered writing unit tests without tools in the earlier part of the course.

15 JUnit

JUnit is a java framework for unit testing. It basically looks for classes and methods with the name "test" in them, and runs all your tests.

You would normally create a test class `DayTest` for example, that extends `TestCase`, a JUnit parent class. This parent class contains all the JUnit "stuff".

16 Javadoc

The importance of documentation is self-evident. Javadoc is a tool that auto-generates an HTML file based on specially formatted comments in your code. They always begin with `/**` (rather than just /*). We then use the @ symbol to specify attributes. (for example: @author Francis Piché, @return int)

Since it gets converted to HTML, you can actually inject html into the comments to add custom formatting!

Part V
Modeling

Software design is the idea of planning before coding. Abstractions and architecture are used to create a full model before beginning the implementation.

The development (which would be done by the programmers) is controlled by the designer by using effective communication, strong OO constructs, and unit testing. The requirements are described by contracts, generalized code and UML (or some other modeling method).

17 UML Class Diagrams

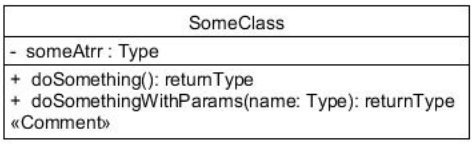
This diagram describes all classes, data structures, objects and what they contain.

You could exhaustively go and model every possible attribute, method etc. But this is really hard to do since it's almost impossible for a designer to forsee every method a programmer would need, without writing anything himself.

In this class, we will make minimal diagrams, where we specify only the minimal variables and methods.

You could also make hybrid responsibility diagrams, where instead of specifying methods you would write a "responsibility" description. (Not done in this course)

A basic class would look like:



Where the + means public and the - means private.

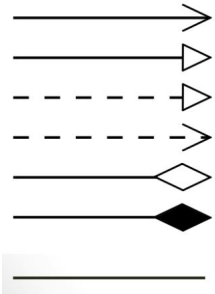
17.1 Relations

Since classes often depend and use each other, we need a way to depict this.

- Association : class A calls a method in class B
- Inheritance : A extends B
- Realization / Implementation : A implements B
- Dependency : A assumes something about B but doesn't use it directly.
- Aggregation : see below
- Composition : see below
- Undirected : Relation in an undefined way.

Aggregation and composition are a little weird to understand. (At least for me!) Class A aggregates class B, if class B can exist without the existence of class A. Meanwhile, Class A composes class B if class B cannot exist without being within class A. `https://www.visual-paradigm.com/guide/uml-unified-modeling-language/uml-aggregation-vs-composition/`

These relationships are expressed with these arrows: (in order)

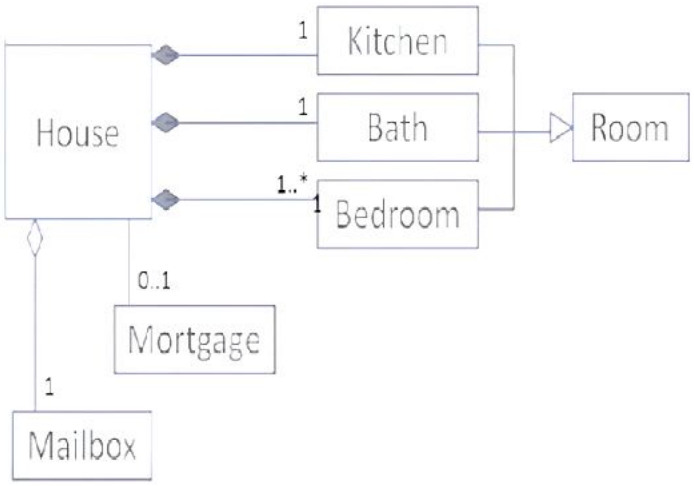


Note that having TONS of arrows is probably a good indication of bad design.

We can also express multiplicity by adding $n..m$ or $0..*$ etc. To show there should be between n to m instances, or 0 to ∞ instances.

17.2 Examples

17.2.1 House



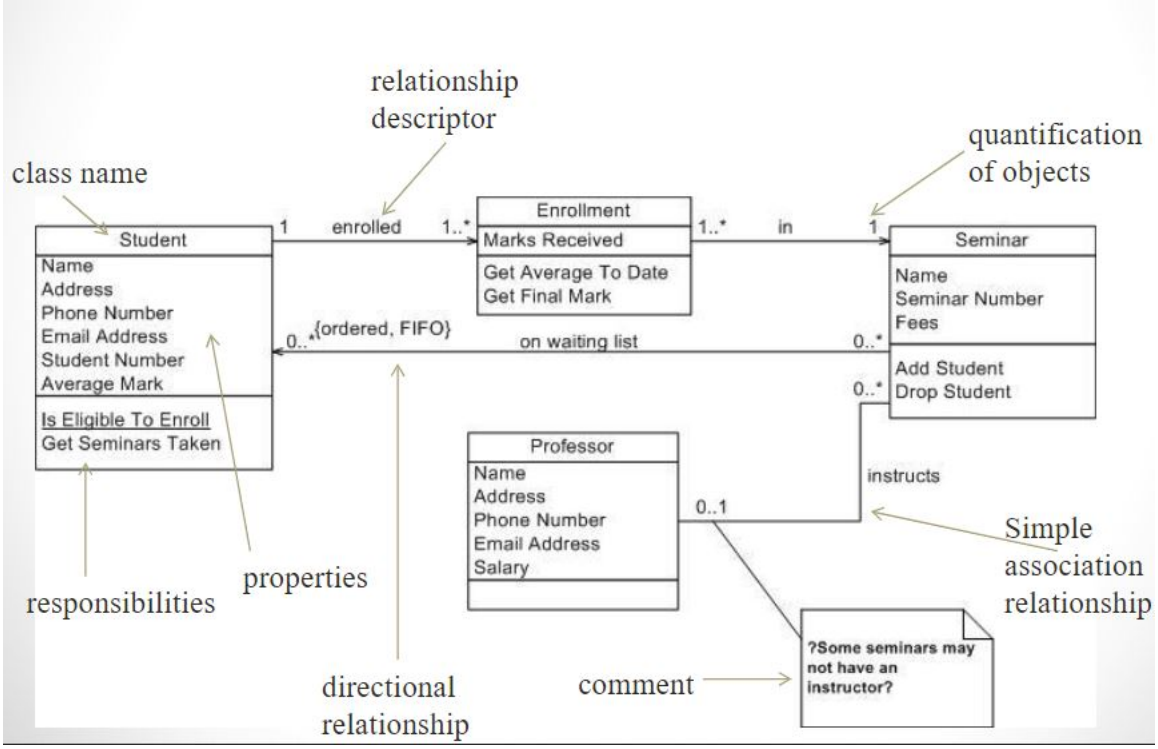
The main method is most likely inside House, since most instantiations are coming out of house.

In this picture, a House must have exactly 1 Kitchen, 1 Bathroom, and 1 to many Bedrooms. All of those extend Room. A Mortgage is somehow related, and can exist or not. A Mailbox is given to the house, but not necessarily part of it. (aggregation).

There is actually a problem with this. Is Mailbox static? If not, then it must be instantiated by something. But this picture says it must be static, but it's also associated to the House using an aggregation, which means it must be instantiated.

We could make this correct by adding another Main class which instantiates Mailbox (and possibly House if we don't want it to be static). **Always think of what needs to be instantiated!!!**

17.2.2 University



Here we are adding labels to the associations. These describe what the relationship actually is.

Notice that Professor has no methods, since they aren't important and we are doing a hybrid responsibility here (even though we said we wouldn't do those!). Meanwhile, Enrollment has some methods since they are important to understanding the situation and requirements.