CITS4401 Software Requirements and Design
Week 10 – Interfaces and system design

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What is an *interface*?

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It just means, "the boundary where two things meet".

Interfaces

In software engineering, we'll usually be interested in situations where at least one of the things provides some sort of *service* to the other.

The interface will be *defined* by

- how and in what format those services are requested
  - including, what must be *provided* when requesting a service, and
  - any *conditions* that must be satisfied
- how and in what format the services are delivered
  - including anything that will be true *after* they've been delivered

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  - Yes! You need to actually have an existing driver's license.
  - And you can't be disqualified (e.g. due to traffic offences committed)
  - And you may have to satisfy some other conditions as well (e.g. proof of eyesight)

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- They will issue you immediately with a paper *temporary* license
- And in the mail, they will send you a new physical driver's license.

In software engineering, we'll usually be interested in the case where at least *one* of the two things involved – usually the thing providing the service – is a computer artifact of some sort (an item of hardware or software).

The thing *requesting* the service might also be a computer artifact, but could be human.

And we will typically want the answers to the questions given in the previous slides to be *clearly defined*.

If the thing requesting the service is a person – a *user* – then the interface is a *user interface*.

Here's an example of a user interface:

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  - They either click one of the buttons on the left, *or*
  - they fill in the text fields, and click the button underneath
- Are there any conditions that must be satisfied in order for the user to request the service?
  - Often, the email address must be in a valid form.
    (Additional validation might get performed later – e.g. by sending a confirmation email – but it's not a precondition for using the form.)

- How is the service delivered?

- How is the service delivered?
  - The "service" just consists in the fact that after having signed up, the user will *have an account*.

If both of the things involved are items of *hardware*, then the service will be specified both in terms of physical connections, and perhaps what sort of signals are passed through it and what they mean.

To specify the hardware interface of the parallel port in the previous slide, we'll specify

- the physical characteristics of the port – exactly what dimensions does it have, and what dimensions and configuration must an appropriate plug have to fit into it?
- often – what signals can be sent across each of the wires the port attaches to, and what they mean.

Software has interfaces to – well-defined ways of requesting some bit of software perform a service. The software could be:

- a method
- a class
- a set of classes

(Also, Java uses the word "interface" to refer to a class-like thing which specifes an interface, but not an implementation.)

If we look up the Java documentation for the String.indexOf()
method, we are told the following:

Its signature is:
    int indexOf(int ch)

That is, it takes an int[1] and returns an int.

_____

[1] Why not a char? For historical reasons we won't get into.

APIs

And also, we are told what this method does:

Returns the index within this string of the first occurrence of the specified character. If a character with value ch occurs in the character sequence represented by this String object, then the index (in Unicode code units) of the first such occurrence is returned. For values of ch in the range from 0 to 0xFFFF (inclusive), this is the smallest value k such that:

this.charAt(k) == ch

is true. For other values of ch, it is the smallest value k such that: this.codePointAt(k) == ch is true. In either case, if no such character occurs in this string, then -1 is returned.

Parameters:

ch - a character (Unicode code point).

Returns:

the index of the first occurrence of the character in the character sequence represented by this object, or -1 if the character does not occur.

APIs

Because it's a method, the way to request a service from the method should be pretty clear to all Java programmers – we *call* the method.

```
String s = "banana";
int res = s.indexOf('a'); // using the service
System.out.println(res);
```

In this case, the service is provided to us in the form of a return value. But other methods (e.g. .println()) might provide their services by *doing* something (printing things to the screen, erasing our hard-disk, launching intercontinental ballistic missiles, etc.).

If the thing we're interested in is a *class*, then it can have both public and private members. We are usually interested in the *public* interface – the set of all public methods and instance variables.

If we have a module – a collection of classes – then

- the specification for all the externally accessible classes, methods and so on in a module make up what is called the *API*[2] of the module – the "Application Programming Interface".

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- (Actually, the other developers might not be writing an *application* per se – they might be writing another library – but the name has stuck.)

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APIs as contracts

- We can think of the API for a function (or other procedural unit) as constituting a *contract* between the developer of the function, and the client code using it.[3]
- In effect, the documentation says "If you, the client code, pass me arguments which meet the following criteria, I promise to do the following thing: ..."

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[3]See further "Design by contract",
https://en.wikipedia.org/wiki/Design_by_contract; Meyer, Bertrand. "Applying 'design by contract'." Computer 25.10 (1992): 40-51.

- The "following thing" – the behaviour of the function – will usually be to return some sort of value, or to cause some sort of "side effect".
- (A *side effect* is anything the function does to alter the current or subsequent behaviour of the system or its interaction with external systems, other than returning a value.
  For example, writing a file to disk, or sending an email, or changing the value of a global variable.)

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  System.out.println("some string ...")

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API example

- If you have used Java, you most likely at some point will have written something like
  `System.out.println("some string ...")`

- What does the `println` method promise to do?

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  void println(String x)
  Prints a String and then terminate the line.

- Does `println()` return a value? If not, then what does it promise to do?

APIs – specification vs implementation

The API documentation does not normally say *how* the function is to be implemented – just what its return value and effects are.

This means that if the library developer decides to reimplement the function in another way (for instance, to improve efficiency), they can, without changing the API.

Specification vs implementation example

In fact, you can have multiple implementations of the same API by different developers.

Example:

- Oracle corporation provides an implementation of the Java standard libraries (as well as of the Java compiler, javac, and the Java Virtual Machine or JVM).
- But there are other implementations – for instance, OpenJDK, an open-source version of the standard libraries.
- These adhere to exactly the same specifications as the Oracle versions.
- (In fact, since Java version 7, the OpenJDK version has been the reference implementation.)

- The POSIX standard specifies an API for Unix-like systems, and has been implemented multiple times in different ways by different operating systems. (In fact, even Windows, at various times, has met the POSIX standards.)

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- But there's nothing in the *specification* to stop us from implementing it in other ways . . .
- e.g. Generate a random number from 0 to (length-of-string - 1), call it k. Check and see if we've hit all positions from 0 to $k - 1$ yet; if we have, and inputString.charAt(k) equals the character we're after, return the current index.[4]

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[4]See also Bogosort, https://en.wikipedia.org/wiki/Bogosort

Sometimes specifications for units will describe not just what the unit *returns* or *does*, but *how it does it*.

For instance, if we implement `String.indexOf(ch)` in the "generate a random number" way we described, it would be *extremely* slow.

The specification of String.indexOf(ch) could rule out "silly" implementations like this, by saying something like "the indexOf method shall provide guaranteed $O(n)$ time cost, where n is the length of the string".

(If you have not done a data structures and algorithms course, don't worry too much about what "$O(n)$" means – it roughly means that the time to execute indexOf will increase in proportion to the length of the string.)

If you look at the documentation for Java's `TreeMap` class, in fact, you will see that the implementation provided by Oracle promises to provide guarantees about how long particular methods will take to run:

> *This implementation provides guaranteed log(n) time cost for the* `containsKey`, `get`, `put` *and* `remove` *operations. Algorithms are adaptations of those in Cormen, Leiserson, and Rivest's Introduction to Algorithms.*

So:

- The API describes the *expected behaviour* of a module (or larger system).
- The code constitutes a particular *implementation* of that API.

What should go in the API documentation?

- The *preconditions* – any conditions which should be satisfied by the parameters or the system state when the function is called.
- The *postconditions* – the return value of the function, and any *changes* the function makes to the system state (the "side effects" discussed earlier)

We often also will document what will happen if the preconditions *aren't* satisfied: in many languages, this will typically be an exception being thrown.

Once we know the preconditions and postconditions for a function, we can write tests for it.

(They needn't be spelled out formally or mathematically – but it is best if they are clear, consistent and unambiguous.)

Developing systems – top-down vs bottom-up

When developing systems there are basically two ways of doing it:

- Top-down, also called "stepwise refinement":
    - Try and break the desired system down into smaller pieces, until we have something we can handle
- Bottom-up:
    - Try and identify individual bits of functionality we can identify, and try to assemble them into a system.

Historically, top-down was once more common. (Well – in practice, projects used a mix of the two.) But in OO systems, something more like bottom-up is more common.

Therefore, in an OO system – often, when we reach the stage of design, we will *already have* a bunch of classes representing functionality we want.

Sometimes, we will need to break those classes down further, because it's not clear how to implement them.

But often, a more important task is to *group classes together* into components and subsystems.