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Interpreted: Basic, HTML, . . .

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- C# (2): You copy how Java shot itself in the foot. Then you explain to everybody who will listen how you did it better
- C# (3): You can create and shoot a gun in C#, but you can't shoot your foot in managed code

Interpreted and Compiled

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- Lua: You come up with a decent way to shoot yourself in the foot, but you're unsure if it's the optimal way to go about it. You ask the mailing list. Someone points out that Lua has a "shoot foot" function built in, but it's only exposed via the C API. The discussion devolves into a long debate about whether various functions should be exposed, how objects and OOP should be implemented, and whether nil should be a valid table index

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Uses the compile-run-edit cycle of development

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Or compile the bytecode to native machine code and run that

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Generally a modest overhead in loss of speed in the execution of the bytecode

Managed and Unmanaged

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The idea that this is a “safe” language, running in a secure *sandbox*, preventing all kinds of nasty things from happening: memory overruns, execution of virus code, connecting to rogue Web sites, and so on

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Inaccurately and misleadingly, but to a decent approximation

$$\begin{aligned} \text{managed} &= \text{bytecode} \\ \text{unmanaged} &= \text{compiled} \end{aligned}$$

and the word “managed” is mostly used to make “unmanaged” sound bad by comparison

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Large overhead in loss of speed as each line of code has to be interpreted before it can be executed

Interpreted and Compiled

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For example, C is almost always compiled, while Basic tends to be interpreted

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Lua is similar to Perl in these respects

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This is important for targeting an application: compactness (for small machines) can be exchanged for raw speed of the running program. Or to allow mobility of the code

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Occasionally JIT can produce faster running code than simple static compilation as the compilation process can be informed by the profile information gained from running the program (e.g., which methods are actually being called)

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Exercise. Look at the optimisations that modern implementations of JavaScript use

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Suitable compilation and optimisation is done just once, when the app is installed

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- less energy used, as we don't repeatedly use energy in doing the same compilation every time the app is run

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- the compiled code takes up more space. Becoming less of an issue as memory capacity on small devices improves

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When your phone is idle it then sneakily uses AOT while you are not looking

And it also uses JIT to tune apps as they run

Interpreted and Compiled

You get the advantages of fast installation and AOT and JIT

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You get the advantages of fast installation and AOT and JIT

But this makes the Android runtime very complicated!

Interpreted and Compiled

Exercise. Look at several languages and determine their usual methods of execution

Exercise. Then determine the positives and negatives of doing it differently (e.g., compiling Java to machine code; bytecoding C)

Exercise. Another approach is for the app store to take the code and compile and pre-optimise it into separate codes for each of the various kinds of hardware out there. Then it delivers the appropriately optimised code at download time. Find out about this

Exercise. How is using AOT different from using a classical compiler?

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“Normal” Compilation

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“Normal” Compilation

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So if the code includes a call `f(x+1,y/2)`, where `f` is defined in another module, the compiler generally only has the type signature `int f(int a, int b)` so it knows enough to generate the correct code to pass the arguments and return the value

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But without knowing more about `f`, it can't do anything clever like that

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Practically, this is clearly quite difficult for larger programs

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Modules are compiled separately as normal, but in the link phase, when all the compiled parts are joined together, the linker can make some optimisations

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Again, technically difficult, but starting to make a big difference

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Run Time Optimisation

The runtime system monitors the program as it is running, and make dynamic optimisations to the code using knowledge of what is actually happening in the code

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Run Time Optimisation

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Used to good effect in JIT compilers

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The rest is easy

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Many people have the implicit assumption that if you know Java then you know all about OO

This is far from the truth: Java way of doing OO is just one way of many

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It is sometimes said that an OO language has

> *“Abstraction, Encapsulation, Inheritance, Polymorphism”*

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We shall see the several ways that this is wrong!

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Classes are secondary, and sometimes not there at all!

Object Oriented Languages

> *It was obvious to me 20-some years ago that OOP wasn't a panacea. That's the reason C++ supports several design and programming styles.*
>
> *In the first edition of "The C++ Programming Language," I didn't use the phrase "object-oriented programming" because I didn't want to feed the hype. One of the problems with OOP is exactly that unscrupulous people have hyped it as a panacea. Overselling something inevitably leads to disappointments.*

Bjarne Stroustrup, Feb 2000

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Simula looks like a mixture of Pascal and Java, and has been described as “Algol plus classes”

Object Oriented Languages

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However, it was with Smalltalk in 1972 that the OO concept really took off

Object Oriented Languages

Feet

- Simula: ?

Object Oriented Languages

Feet

- Simula: ?
- Smalltalk: You send the message shoot to gun, with selectors bullet and myFoot. A window pops up saying Gunpowder doesNotUnderstand: spark. After several fruitless hours spent browsing the methods for Trigger, FiringPin and IdealGas, you take the easy way out and create ShotFoot, a subclass of Foot with an additional instance variable bulletHole

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But still very powerful

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Reflection is where the system can go in and modify things, too

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This is more like `2.plus(3)` in Java-like syntax

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And many different styles of OO were proposed including features called *prototyping* and *delegation*, and then Lisp-based languages featuring multiple inheritance and metaobject protocols

But we shall start with the most familiar kind of OO: that typified by having classes arranged in a hierarchy

Object Oriented Languages

Class Hierarchy

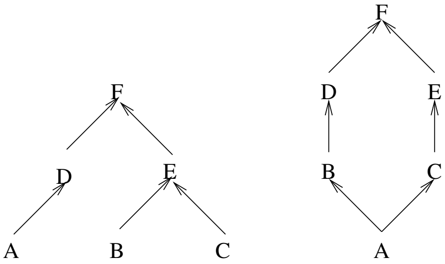
The *class hierarchy* is the relationship between classes

Object Oriented Languages

Class Hierarchy

The *class hierarchy* is the relationship between classes

This can be in a *graph*, where a class inherits from a single parent class; or a *directed acyclic graph* (DAG) when classes can inherit from more than one parent



A Graph and a DAG

Object Oriented Languages

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Thus we do not allow loops in the class hierarchy

Object Oriented Languages

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Object Oriented Languages

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Exercise. But look up `java.lang.reflect`

Object Oriented Languages

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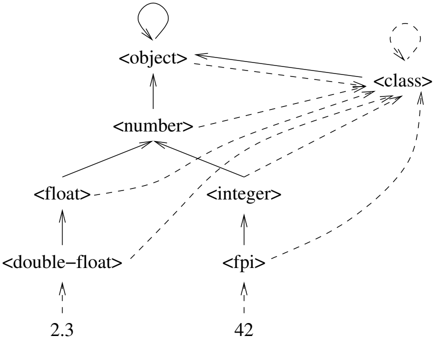
A language will have a default hierarchy of those classes that come with the language

Object Oriented Languages



Part of the EuLisp Class Hierarchy (simplified)

There are *two* hierarchies in this diagram

Dotted arrow is *instance of*/*member of*/*is a*; solid arrow is *inherits from*/*subclass*/*extends*/*subset*

Object Oriented Languages

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Of course, it may override or add to either: generally you override methods, but add to attributes

Object Oriented Languages

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And `<class>` inherits from `<object>`

`<object>` inherits from itself

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The class `<object>` is an instance of the class `<class>`

Of course, the class `<class>` is an instance of itself

Object Oriented Languages

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And two kinds of object: classes and non-classes

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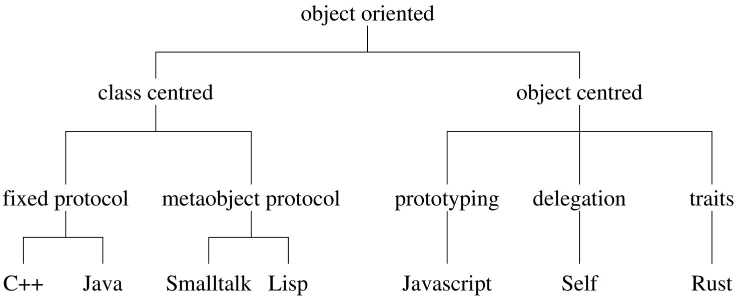
Other kinds of OO dispense with one or both of these relationships

Or one of these kinds of object: the classes

Object Oriented Languages

Exercise. For Java, C++, Common Lisp, EuLisp and any others determine their initial class hierarchy

Object Oriented Languages



object oriented

class centred

object centred

fixed protocol

metaobject protocol

prototyping

delegation

traits

C++

Java

Smalltalk

Lisp

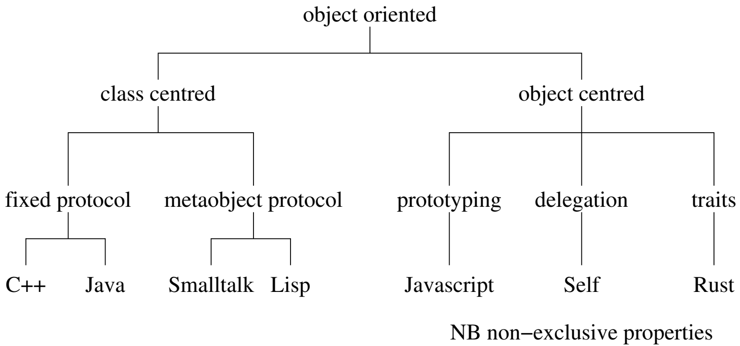
Javascript

Self

Rust

NB non–exclusive properties

Object Oriented Languages



Exercise. In this picture, determine which are instance links and which are inheritance links!