Object Oriented Languages

Method Composition

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Object Oriented Languages

Method Composition

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- The `super` keyword in Smalltalk allows a method to call the next most specific method
- `call-next-method` in Lisp and `super()` in Python are similar
- many languages only have composition in constructors

Object Oriented Languages

Method Composition

- Common Lisp also has *before*, *after* and *around* composition: they call it method *combination*. These add a method to a generic function that runs before, or after, or instead of the existing method

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Object Oriented Languages

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- You can use `call-next-method` to get at the original method from an around method
- Some languages allow arbitrary user-defined method composition: we shall talk about *metaobject protocols* soon

Object Oriented Languages

Method Composition

This is another big reason is why methods are different from functions: with method composition, methods need to know about other applicable methods, while functions live in isolation

Object Oriented Languages

Multiple Inheritance

Next there is another question to tackle: method (and attribute) selection when we have multiple inheritance in the class hierarchy

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Object Oriented Languages

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Take care here: MI is classes having multiple parents, while multiple dispatch is choosing a method using multiple arguments

Of course, we can have multiple dispatch with SI, and single dispatch with MI, and multiple dispatch with MI

Object Oriented Languages

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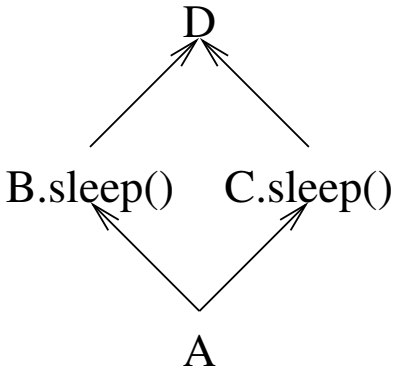
More generally: for method composition we need an order on *all* the superclasses

Object Oriented Languages

Multiple Inheritance



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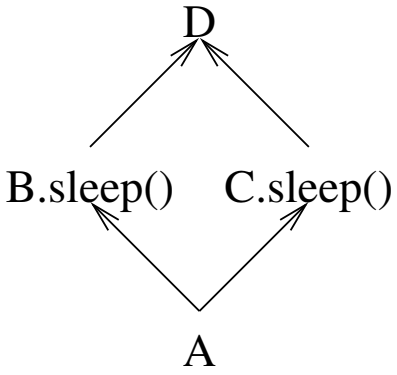
Object Oriented Languages

Multiple Inheritance



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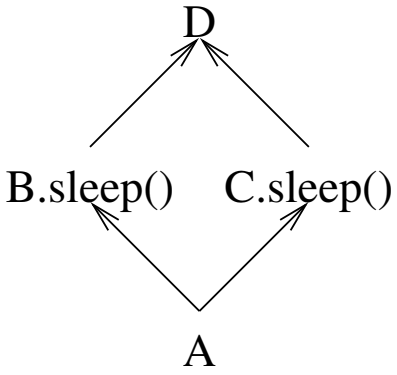

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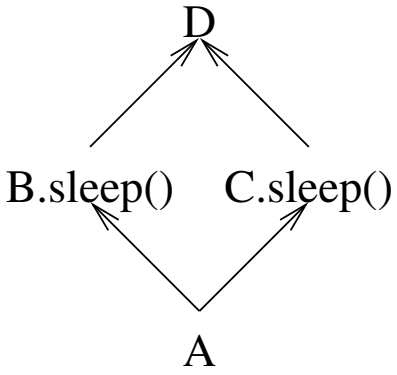

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Object Oriented Languages

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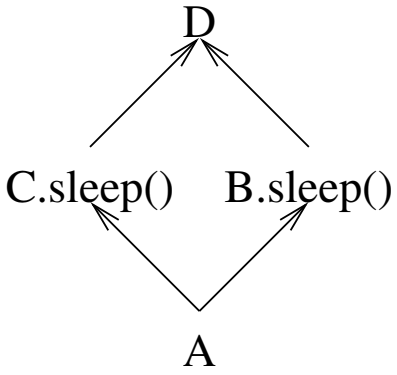

Inheritance diamond reversed

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If `sleep` is called with argument in class `A` should it use the method from `B` or `C`?

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Object Oriented Languages

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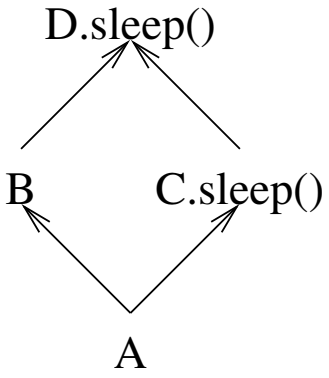

Inheriting from different “levels”

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Object Oriented Languages

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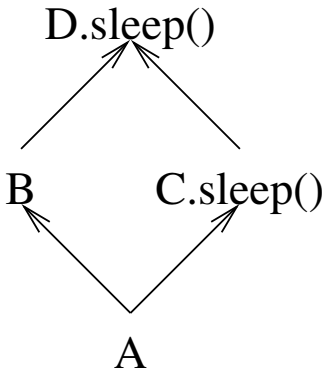

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Object Oriented Languages

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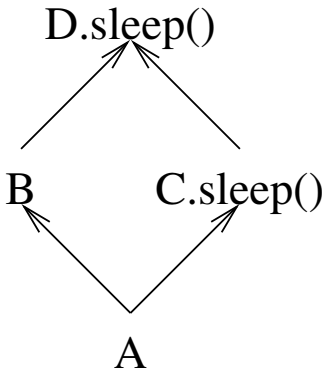

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Object Oriented Languages

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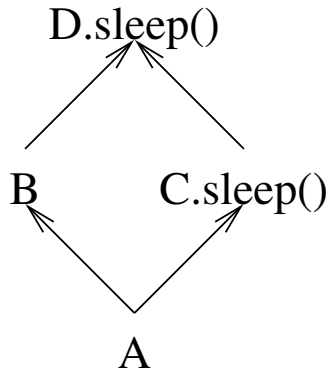

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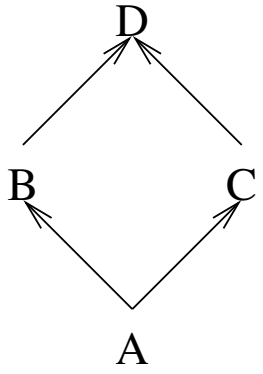
What should `A` do?

Object Oriented Languages

Multiple Inheritance



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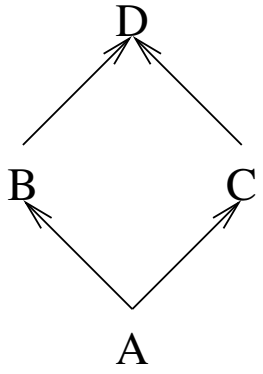
Object Oriented Languages

Multiple Inheritance



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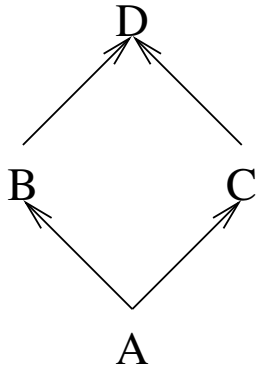

Inheritance diamond

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When there is more than one candidate method to call, how does the compiler (or interpreter) choose which one?

But, remember, the programmer also has to understand how a method is chosen

Object Oriented Languages

Multiple Inheritance

There have been many attempts to address this question

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Some languages force you to disambiguate yourself, e.g., `D::sleep()`

While many languages have a built-in algorithm to choose for you (see linearisation, below)

Object Oriented Languages

Multiple Inheritance

But does this built-in algorithmic choice reflect the expectations of the programmer?

Object Oriented Languages

Multiple Inheritance

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Usually yes in simple cases, but what about more complex hierarchies?

Object Oriented Languages

Multiple Inheritance

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Usually yes in simple cases, but what about more complex hierarchies?

The fact there are many linearisation algorithms tells us something!

Object Oriented Languages

Multiple Inheritance

For example, in simple cases, Common Lisp makes a choice by looking at how the classes were defined

Object Oriented Languages

Multiple Inheritance

If the definition was

```
(defclass D () ...)
(defclass B (D) ...)
(defclass C (D) ...)
(defclass A (B C) ...)
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it might order the diamond of superclasses of `A` as `(A B C D)`.

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And similarly for `B` vs. `D`

Object Oriented Languages

Multiple Inheritance

On the other hand, if we happened to define

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Remember this is a tiny example: in reality the code will be much more complicated

Object Oriented Languages

Multiple Inheritance

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Object Oriented Languages

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Object Oriented Languages

Multiple Inheritance

A class precedence list helps the language decide which method to use

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Namely the ordering of the applicable methods so we (a) can pick the right method and (b) have an ordered list of methods for method composition

Object Oriented Languages

Multiple Inheritance

In object-receiver languages, usually the method chosen is the earliest found following the CPL

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Thus if the CPL is `(A B C D)` and both `B` and `C` define `sleep`, then pick the method from `B`

If just `D` and `C` define `sleep`, then pick the method from `C`

Object Oriented Languages

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With object receiver, the MRO is just the CPL; with multimethods calculating the MRO is harder (coming soon!)

Object Oriented Languages

Multiple Inheritance

Computing a good CPL is not straightforward: what about `D` and `E` in

```
(defclass F () ...)
(defclass E (F) ...)
(defclass D (F) ...)
(defclass B (D) ...)
(defclass C (E) ...)
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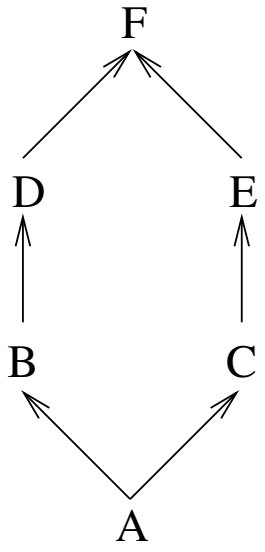
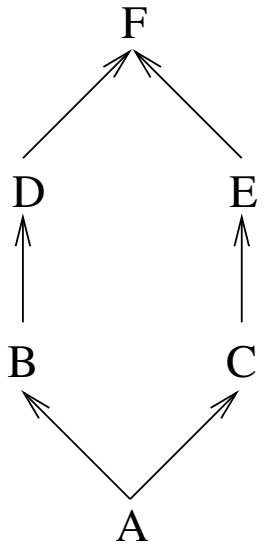
Object Oriented Languages



MI graph with no disambiguating definition

There is no disambiguating `defclass` to guide us to order `D` and `E`

Object Oriented Languages



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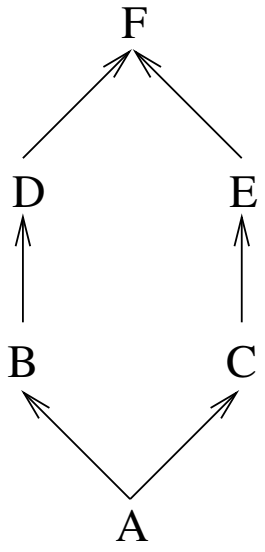

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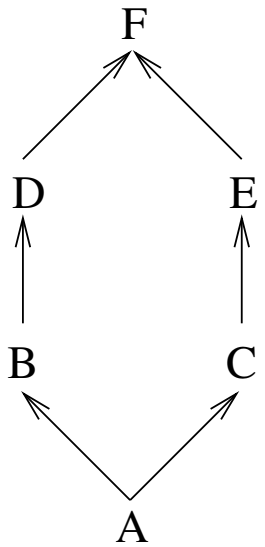

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And do we want `D` before or after `C`?

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Object Oriented Languages

This is the basic problem with MI: it is not clear, and different programmers may have different expectations of what should happen

The class definitions do not help in this example, so we need a little more help

We have two dimensions: left-right and up-down, and different people have different ideas (or different requirements) on which should be used to resolve the order

Object Oriented Languages

Multiple Inheritance

These ideas were first explored in Lisp, and different people made different choices, of course

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The same traversal becomes the CPL `(A B D C E F)`

Object Oriented Languages

Multiple Inheritance

Neither are satisfactory algorithms

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Object Oriented Languages

Multiple Inheritance

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For example, FLAVORS has `F` before `C` in the CPL for `A` even though `C` is a subclass of `F`

And both produce undesirable behaviour in complicated hierarchies

Object Oriented Languages

Multiple Inheritance

For example, if `S` has CPL with `T` before `U`, we might hope that a subclass `R` of `S` also has a consistent CPL with `T` and `U` in the same order

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This would be a *monotonic* CPL: the CPL of a class is consistent with the CPL of its parents

Object Oriented Languages

Multiple Inheritance

Being monotonic is a desirable property as it agrees with intuition of the programmer on how inheritance should happen

Object Oriented Languages

Multiple Inheritance

Being monotonic is a desirable property as it agrees with intuition of the programmer on how inheritance should happen

But many linearisation algorithms don't guarantee that: they might give non-monotonic CPLs

Object Oriented Languages

Multiple Inheritance

All of LOOPS, FLAVORS and the more complex algorithm actually used by Common Lisp can produce non-monotonic CPLs, even on quite small examples

Object Oriented Languages

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All of LOOPS, FLAVORS and the more complex algorithm actually used by Common Lisp can produce non-monotonic CPLs, even on quite small examples

Exercise Look up the CLOS algorithm and find some non-monotonic examples

Object Oriented Languages

Multiple Inheritance

Exercise Think about

```
(defclass D () ...)
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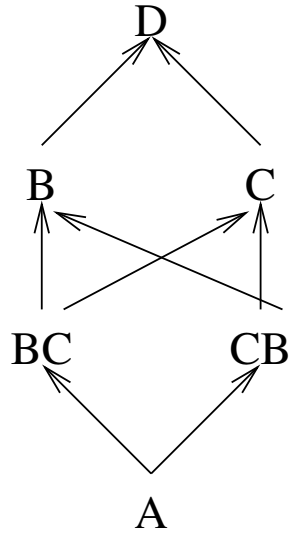

A problematic MI graph

Object Oriented Languages

Multiple Inheritance

Many languages have moved to a linearisation algorithm called C3

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Exercise Read about C3 linearization

Object Oriented Languages

Multiple Inheritance

Some examples of “typical” MI hierarchies, from “A Monotonic Superclass Linearization for Dylan”, Barrett et al., 1996:

	classes	MI joins
LispWorks	507	70
CLIM	842	184
database	38	4
emulator	571	205
proprietary	665	124
Watson	673	114

Feet

- Dylan: tries to shoot you in the foot like Scheme while enviously watching Java eat its lunch

Object Oriented Languages

Method Dispatch

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We need to find the right method to call given a bunch of arguments

This needs various bits of infrastructure to work

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For example, the arguments `(4.0 99)`

The argument of 4.0 might have CPL
`(double float number object)`

While the argument of 99 might have CPL
`(int integer number object)`

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A method is *applicable* to a call with arguments $(a_1, a_2, \ldots, a_n)$ if it is defined for classes $(A_1, A_2, \ldots, A_n)$ where for each i, the class of a_i is a subclass of A_i

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But not applicable to a call with arguments `(4.0 99)` as `4.0` has class `double` which is not a subclass of `integer`

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So a method with *domain* `(integer number)` is applicable to a call with arguments `(23 42)` as these arguments have classes `(int int)`

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But not applicable to a call with arguments `(4.0 99)` as `4.0` has class `double` which is not a subclass of `integer`

Nor a call `(4 "hello")`, even though 4, with class `int` is a subclass of `integer`, we see that `string` is not a subclass of `number`

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Next, a method with domain $(A_1, A_2, \ldots, A_n)$ is *more specific* than a method with domain $(B_1, B_2, \ldots, B_n)$ for the arguments $(a_1, a_2, \ldots, a_n)$ if

1. they are both applicable to $(a_1, a_2, \ldots, a_n)$ and
2. there is an k with $A_i = B_i$ for $i < k$, but
3. A_k appears before B_k in the CPL for argument a_k

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We naturally extend to, say, “cat1” before “cat3” as “1” comes before “3”. But now there is more than one order in play

Or even “c♡9” before “c♣1” if “♡” is before “♣”. Each character position has its own alphabet

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The CPL for the first argument is `(int integer number object)`

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Example. Calling a method with arguments `(1 1.0)` of classes `int` and `double`

The CPL for the first argument is `(int integer number object)`

The CPL for the second argument is `(double float number object)`

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Just as “cup” is before “dog”: even though the second argument is very late in the alphabet, the first argument prevails

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A method with domain `(integer float)` is more specific than one with domain `(integer number)`

A method with domain `(int object)` is more specific than one with domain `(integer double)`

Just as “cup” is before “dog”: even though the second argument is very late in the alphabet, the first argument prevails

A method with domain `(float float)` is not applicable for those arguments unless the language allows automatic coercion of types: a huge extra complication that we shall ignore