# UML for code design

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High Performance
Real Time Lab


TECHNICAL DEBT
I DON'T UNDERSTAND WHY IT TAKES SO LONG TO ADD A NEW WINDOW.
@VINCENTDNL

# UML (standard) diagrams

Structural diagrams

- Use-cases/scenarios
- Notations for classes/objects/packages/components – From OOP
- Deployment/components } won't see these

Behavioral diagrams

- Sequence diagrams
- State diagrams
- Activity diagrams

# Now, let's code

UML provide abstractions to design how the code should look like

- From this perspective, what matter is **data**
- Previously, we focused on entities as system parts/units/components
- We modeled their behavior with sequence diagrams, under different use cases (streamlined from the requirement analysis)

Now, we need to switch to a lower abstraction level, and "look" at entities

- ER diagrams for DBs (already covered in other course)
- Z diagrams for algorithm
- Class/objects[/packages] for OOP

*Remember, the goal of UML is to clearly define*

*what every part of the system does,*

*and how it interacts with the other parts*

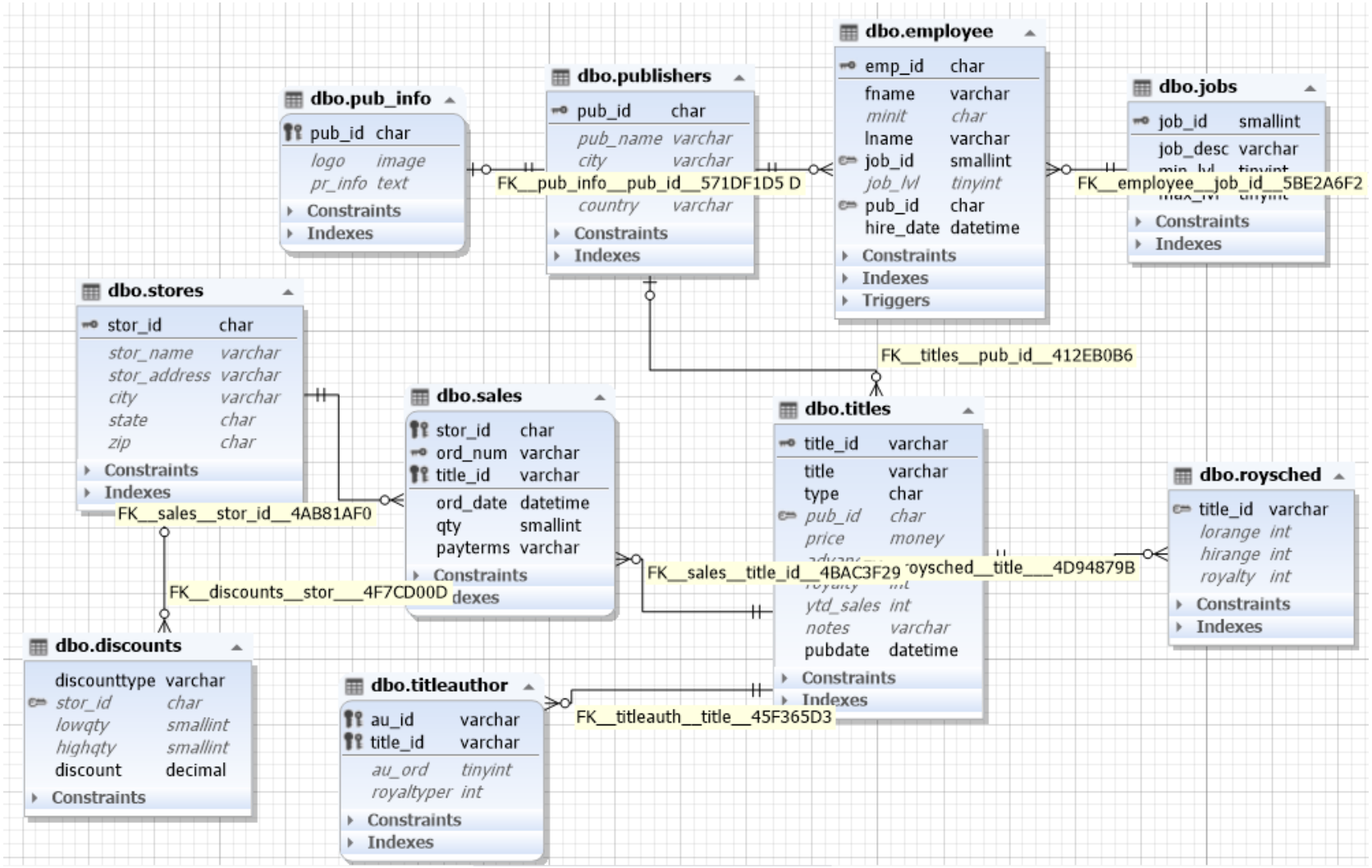
# ER model from the SW engineering perspective

- The result of our analysis phase
- Identifies what data is created, and required by business processes
- Describes system components as blocks, and the relations among them

Typically, used to model our DB

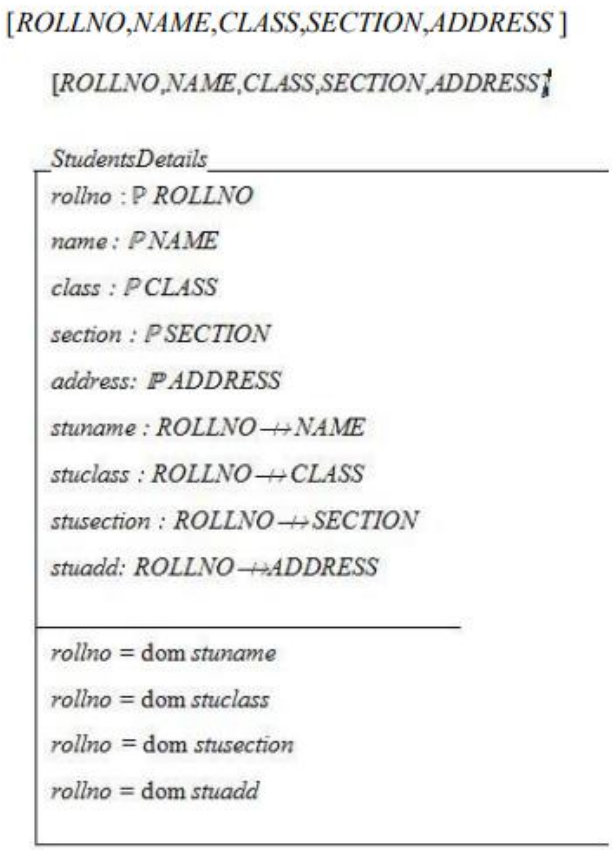
- Remember, we are **data architects**
- We can use tool to generate the code (model and driver) to interact with the DB

# ER model from the SW engineering perspective



# Z diagrams

- Formal specification language that aims at clearly identifying what a computer system does, and how it is done
- Based on mathematical concepts such as lambda calculus, first order predicate logic…
- ISO13568 (2002)




## Pros

- Typed formalism
- Formally correct

## Cons

- Complex to use

# Class diagrams

# Class diagrams

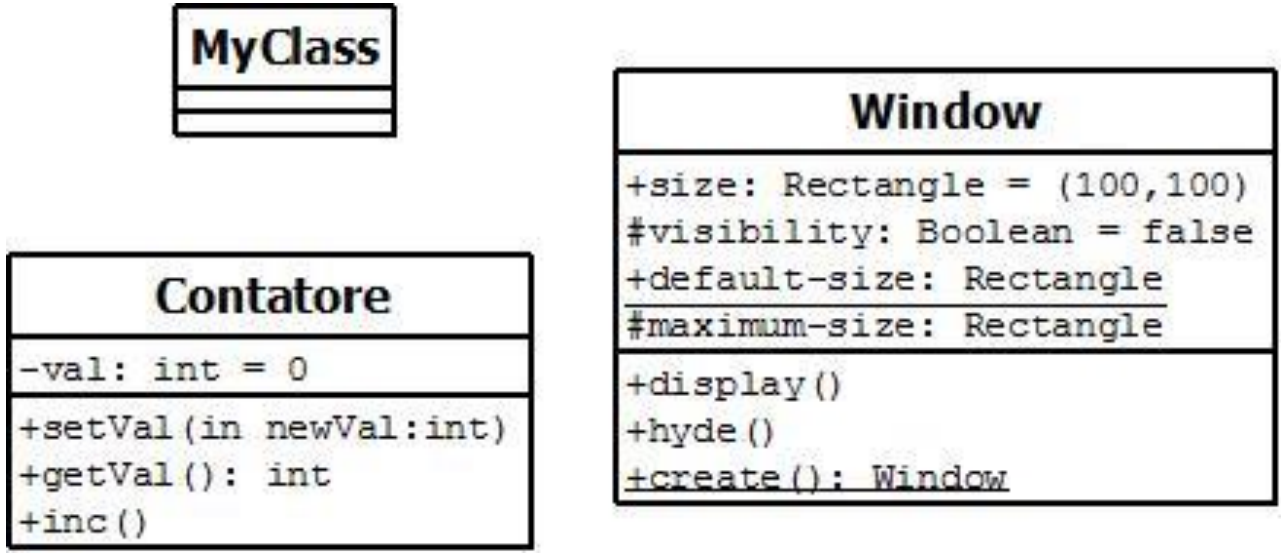
- A graph that (clearly) describes classes/interfaces and their relations by means of nodes and arcs
- Can be used to group elements within packages, or subsystems
- Used to model the static behavior of our system (i.e., classes), something that we can define at compile time

*Why is it so important to define what happens at compile time vs. what happens at run-time?*

# The right abstraction

We need to model each entity (here, class) by the only properties that are of our interest

- E.g., in a gym club, we might want to model people age, weight, height…, while our bank account only models our age
- The only way to master complexity…is to reduce it!



# OOP recap

What is a class?

What is an object?

Why are them ...and OOP... so powerful?

# OOP recap

What is a class?

- **Abstract** concept
- A descriptor of a set of object with common attributes, operations, relations, and behavior
- Groups data (fields) and operations (methods) for a specific set of objects
- *Philosophical pills: this breaks **S**OLID…we will see it later*

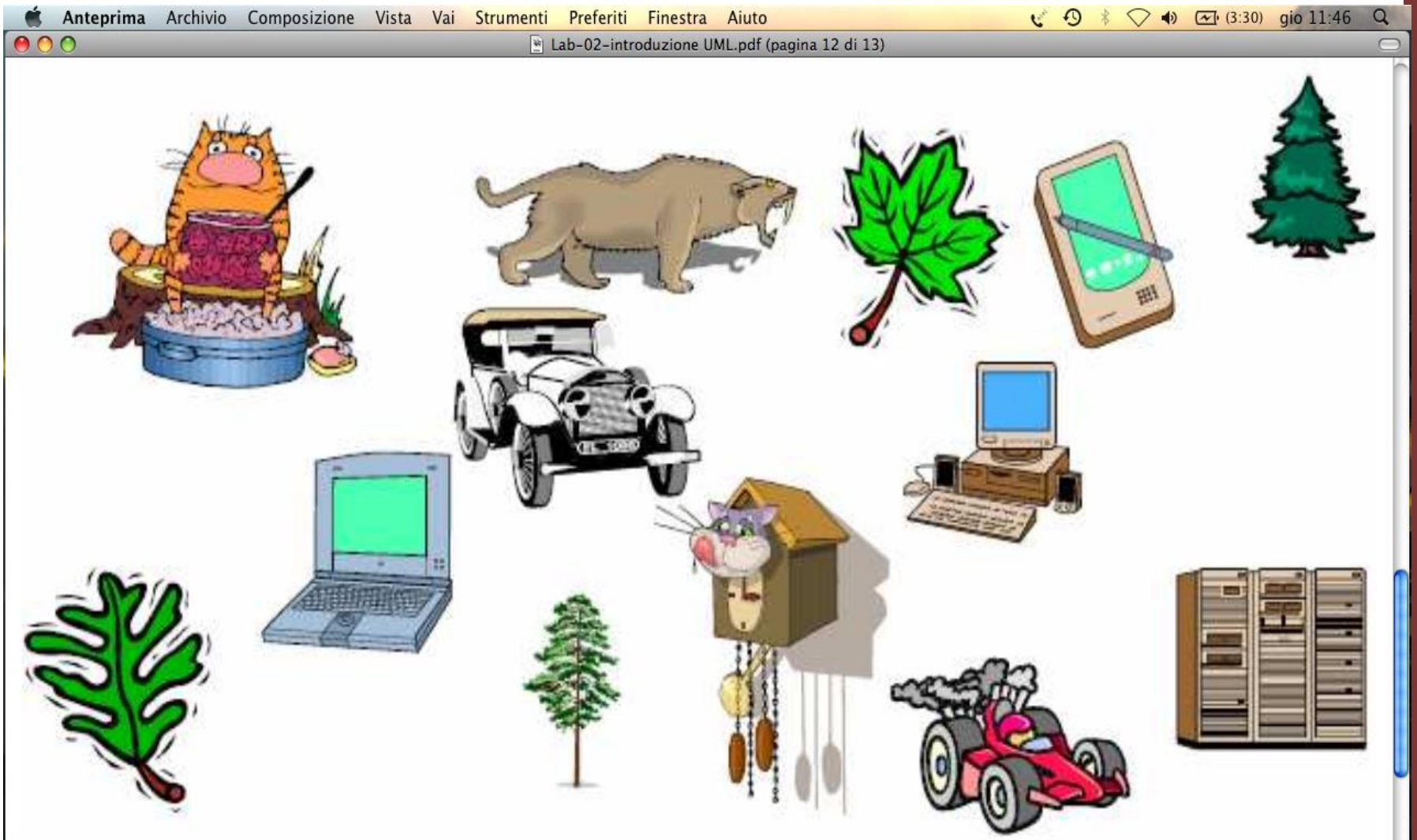
What is an object?

- Is a **concrete** instance of a class

Why are them …and OOP… so powerful?

- Enable classifying, and organizing, the domain, and knowledge of our problem
- Coming from the analysis/system design phase
- Ultimately, to correctly translating them into a code artifact

# Example: how many classes?



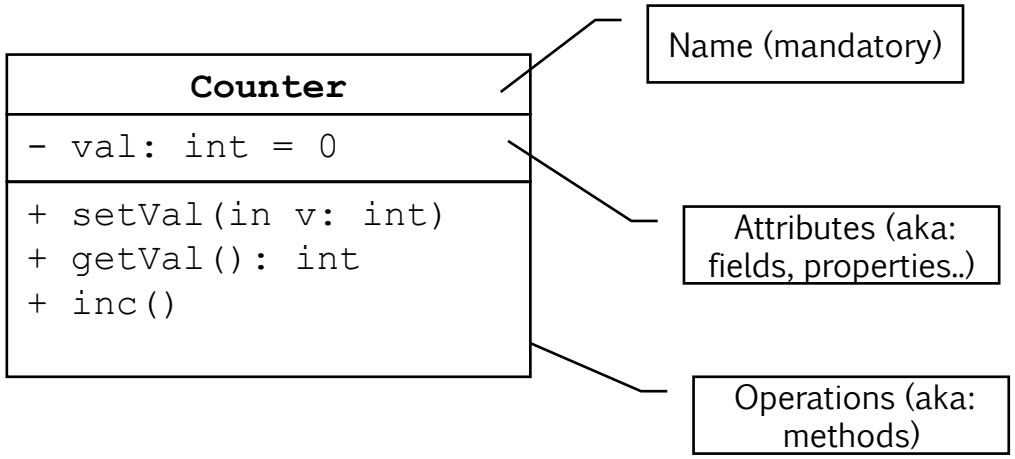

› We are forced to identify a proper abstraction level!

# Basic representation

- "A descriptor of a set of object with common attributes, operations, relations, and behavior"
- A rectangle divided in three parts (similar to object diagrams…we'll see them later)

Note how they introduce the concepts of

- data type
- assignment
- Visibility (+ for public, - for private)

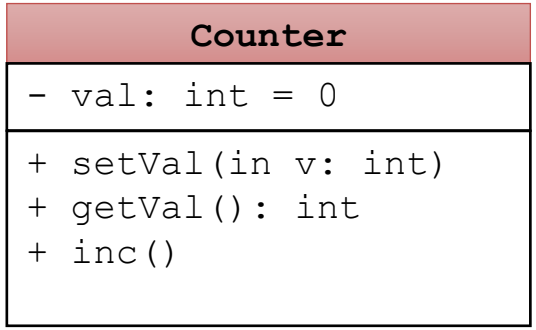


# Name

A string of text

- Must start with capital letter (Java-style)
- Can be *prefix* + "`::`" + *name*
- No special characters ($, %, &)
  - why?

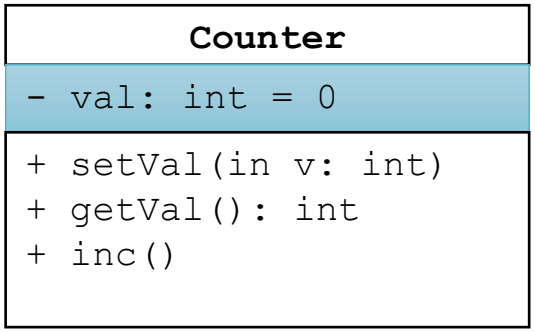
- Non-ambiguous



# Attributes

*<visibility> <name> <[cardinality]>* **:** *<type>* [ **=** *<initial value>* ]

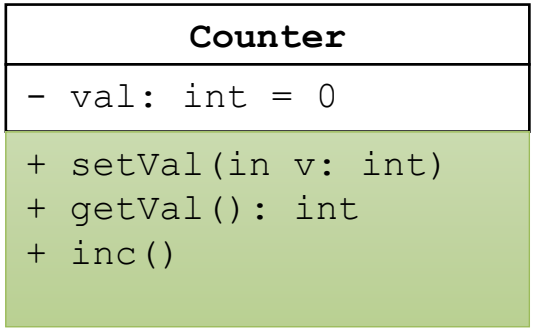
- Name is mandatory
- Visibility
  - **-** for private
  - **+** for public
  - **~** for package
  - **#** for protected
- Cardinality `[n]` for arrays
- `Static` attributes are underlined



# Operations

*<visibility> <name> (<param>: <type>, ..): <ret val type>*

- Only name is mandatory
- `Static` methods and `ctors` are underlined
- Parameters can be preceded by a modifier: `in`, `out`, `inout`
- Non-Java style



# Types of operations

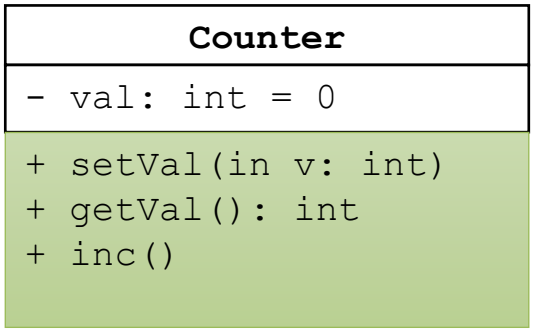
Queries

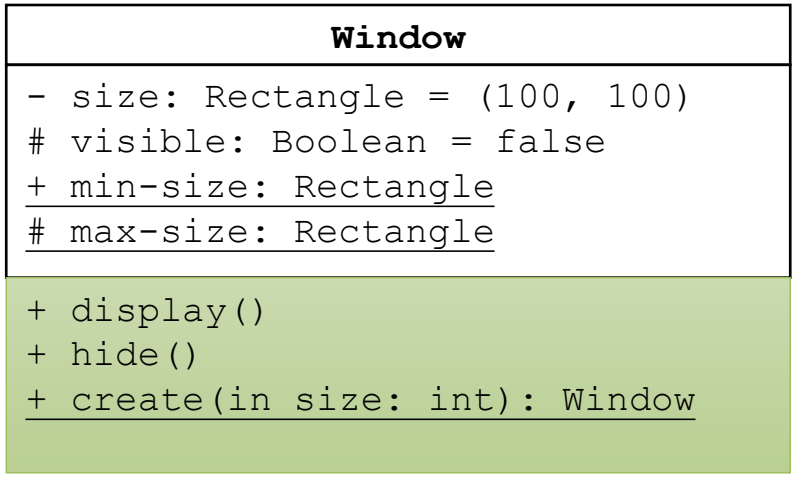
- (ex: Get-ters)
- Do not modify the status

Modifiers

- (ex: Set-ters)
- Modify the status

Ctors to create new instances

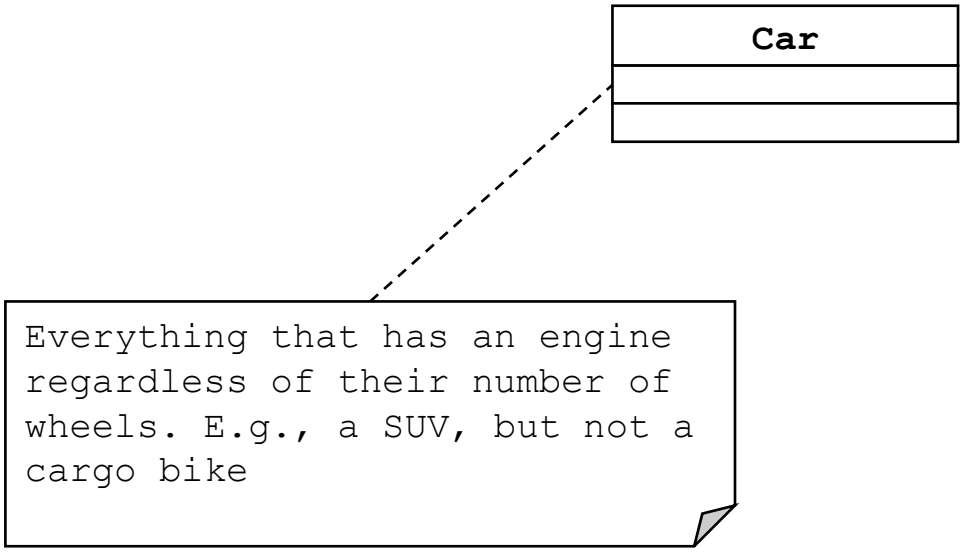


# Adding notes and comments

Do not underestimate comments!!

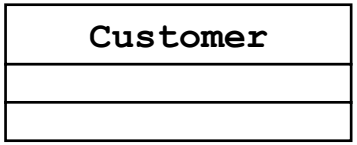
- We can automatically generate code (and their comments) by this
- We can automatically generate (technical) documentation by code comments
- We will have a dedicated lesson on that



# Relation between classes

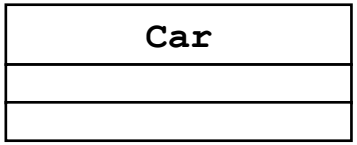
Associations

› Simple, aggregation, and composition



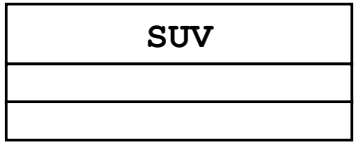

Dependency

› "Uses"




Generalization/specialization

› Has to do with inheritance and interfaces



# Simple association

A solid line between classes

› Arrows specify directions (No arrow: bidirectional) – aka *navigability*

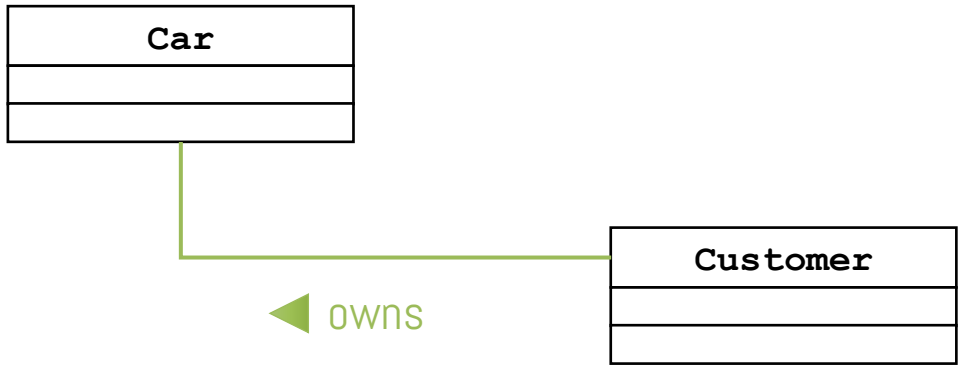
Features

› Name

› Roles

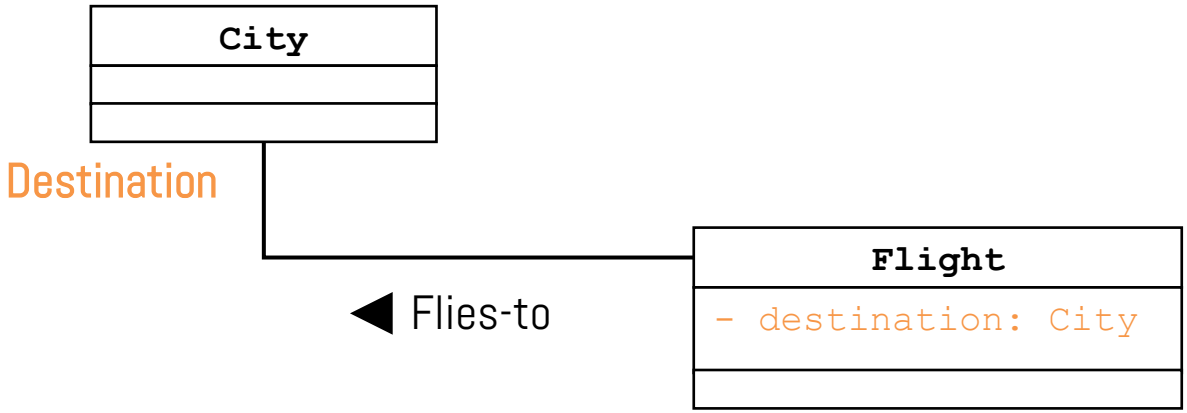
› Cardinality

› Navigability



# Association: role names

- Goes in the direction of creating reference/fields
- Mandatory for reflective relations (between the same class) – we'll see them soon



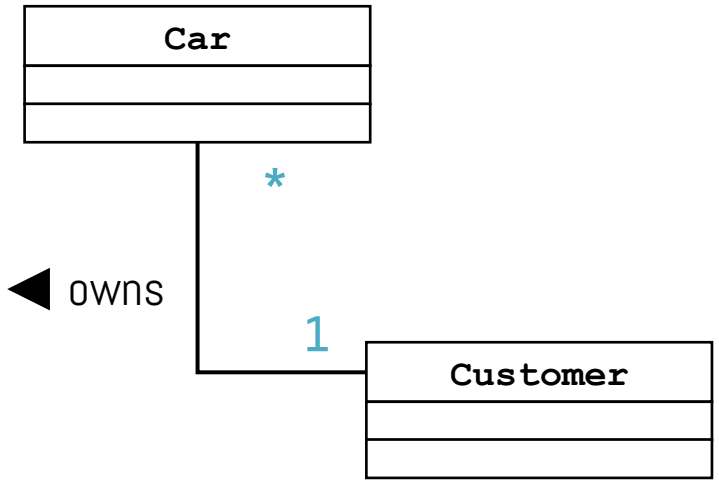
# Association: cardinality

- Gives an information/bound to the number of objects that can participate to an association
- Useful information for programmers!!

Can be

- A symbol (*0 1 **)
- An interval (*1…6* means "*from one to six*")
- Comma-separated list

  (*1..3, 10…20* means *"1..3 or 10…20"*)

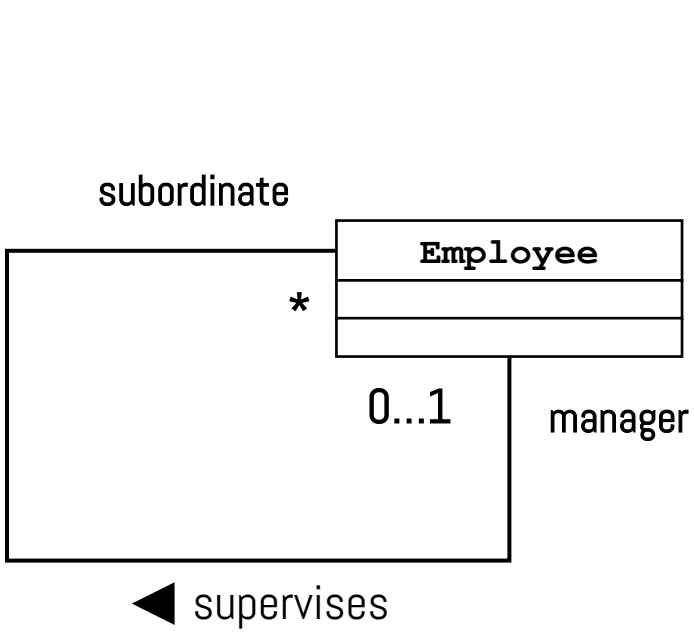


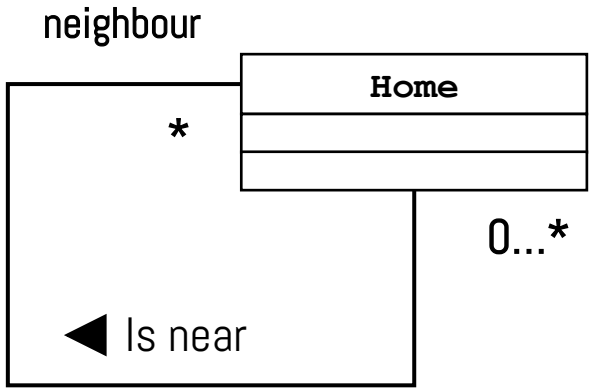

Notes

- Use *to specify any number
- **and *0…** are the same thing
- Often, *replaced with *N*

# Association: reflective

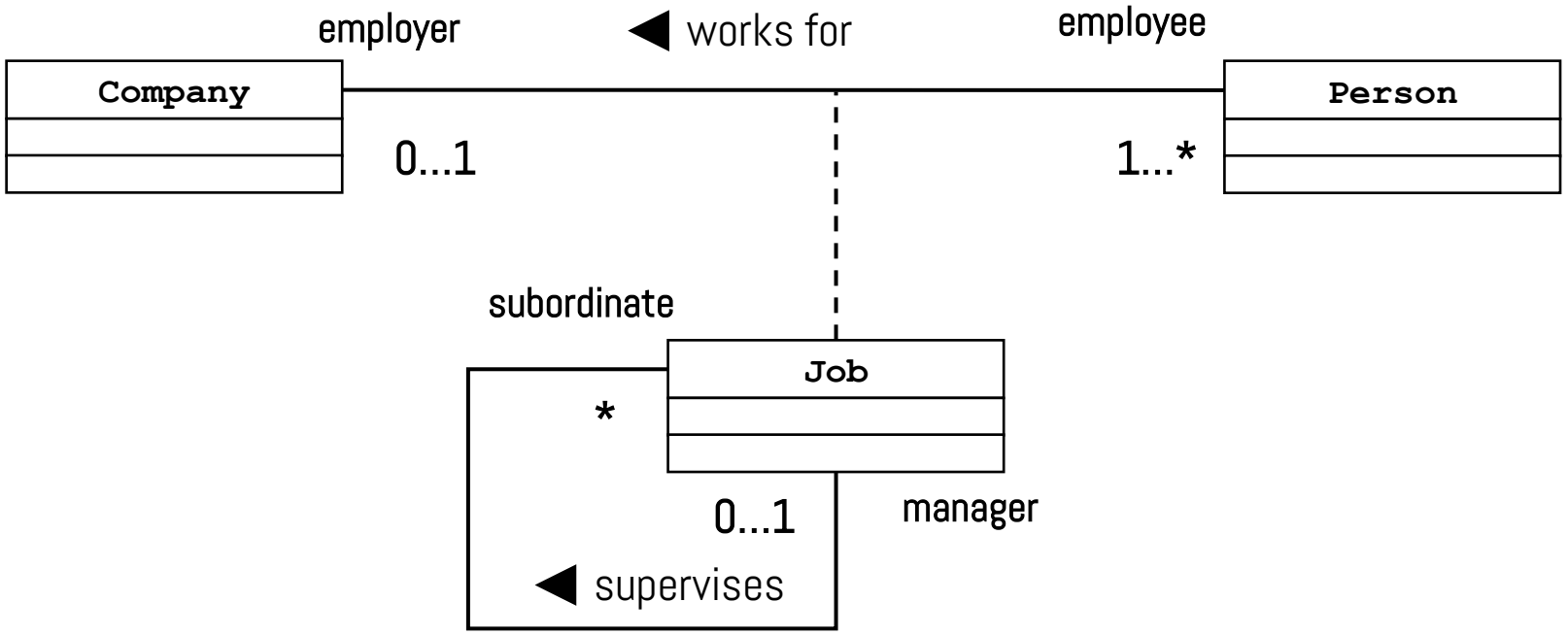
› In this case, roles are mandatory



# Association classes

- Is a class that specifies an association
- Dotted line
- Defines operations, and attributes for that association



# Aggregations

A class that contains another class (logically or even physically)

› Indicates that objects of that class are part of objects of another class

What makes them different by “normal” fields?

› The contained class has its own lifecycle

› Should ring a bell..

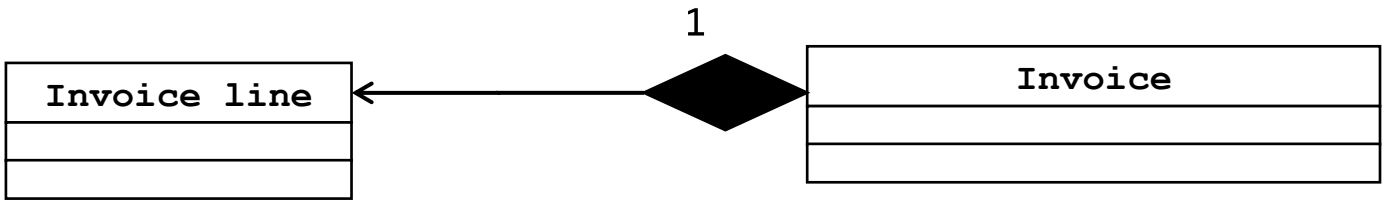
Modeled as **empy** rhombus (with cardinality) close to the containing class

# Compositions

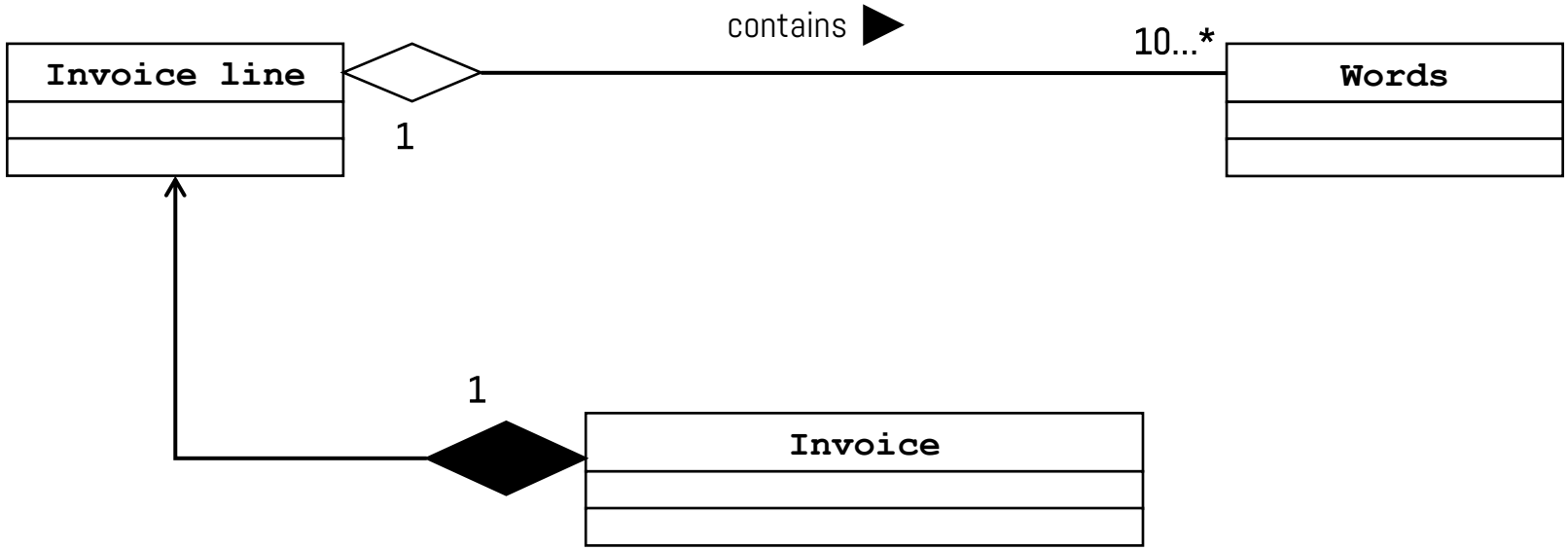
Are strong aggregations

- Indicates that objects of that class are part of objects of another class
- The contained class **doesn't have** has its own lifecycle: only containing object can create and destroy its parts
- Cardinality is 1 (in every instant) – *"Every cost entry can belong only to one invoice"*

Modeled as **filled** rhombus (with cardinality) close to the containing class



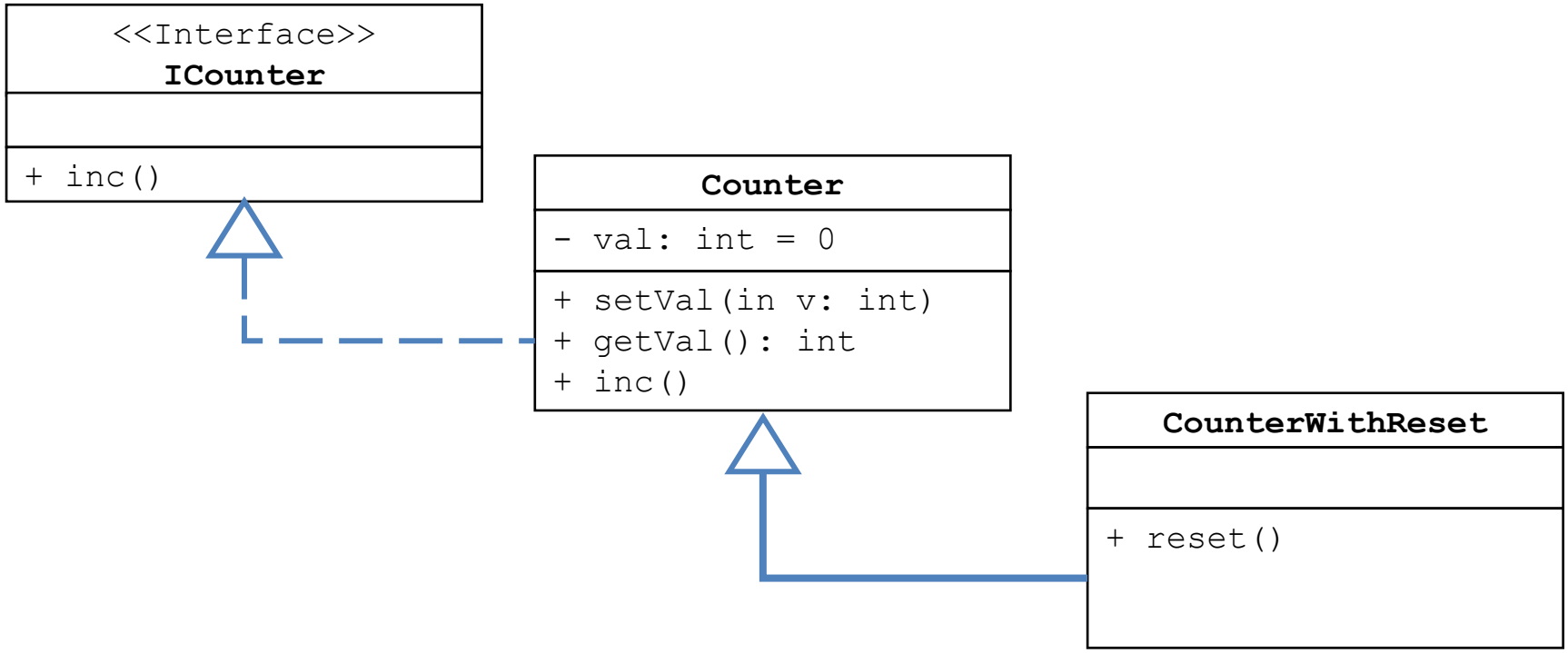
# Compositions...and aggregations



# Generalization/specialization

The typical relation in OOP

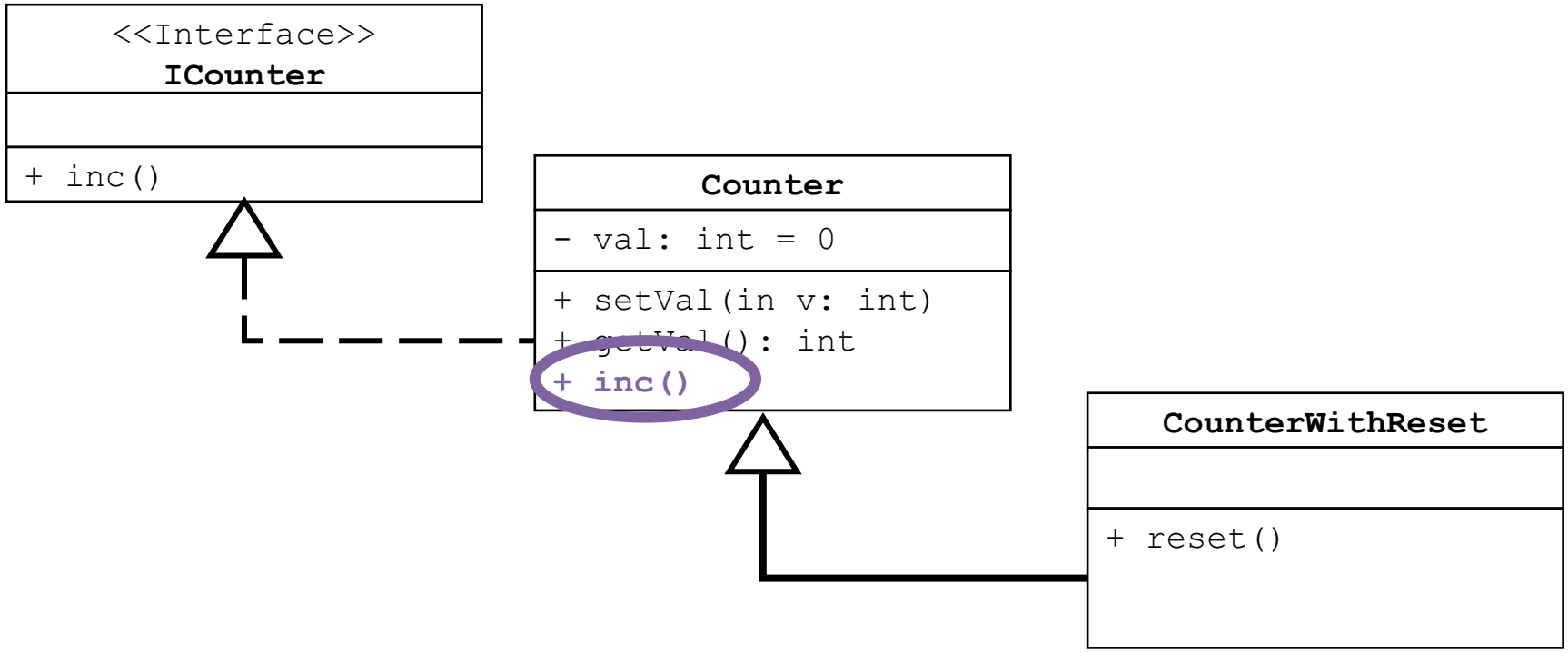
- Models "parent-child" relations, where child class(es) specify (*"override"*) the behavior
- Not limited to OO code!
- Dashed (subclass) or dotted (interfaces) line with empty arrow



# Inheritance

Basic principles

- Properties in super-classes are also in sub-classes
- We do not write it (unless we override it)
- Visibility rules apply

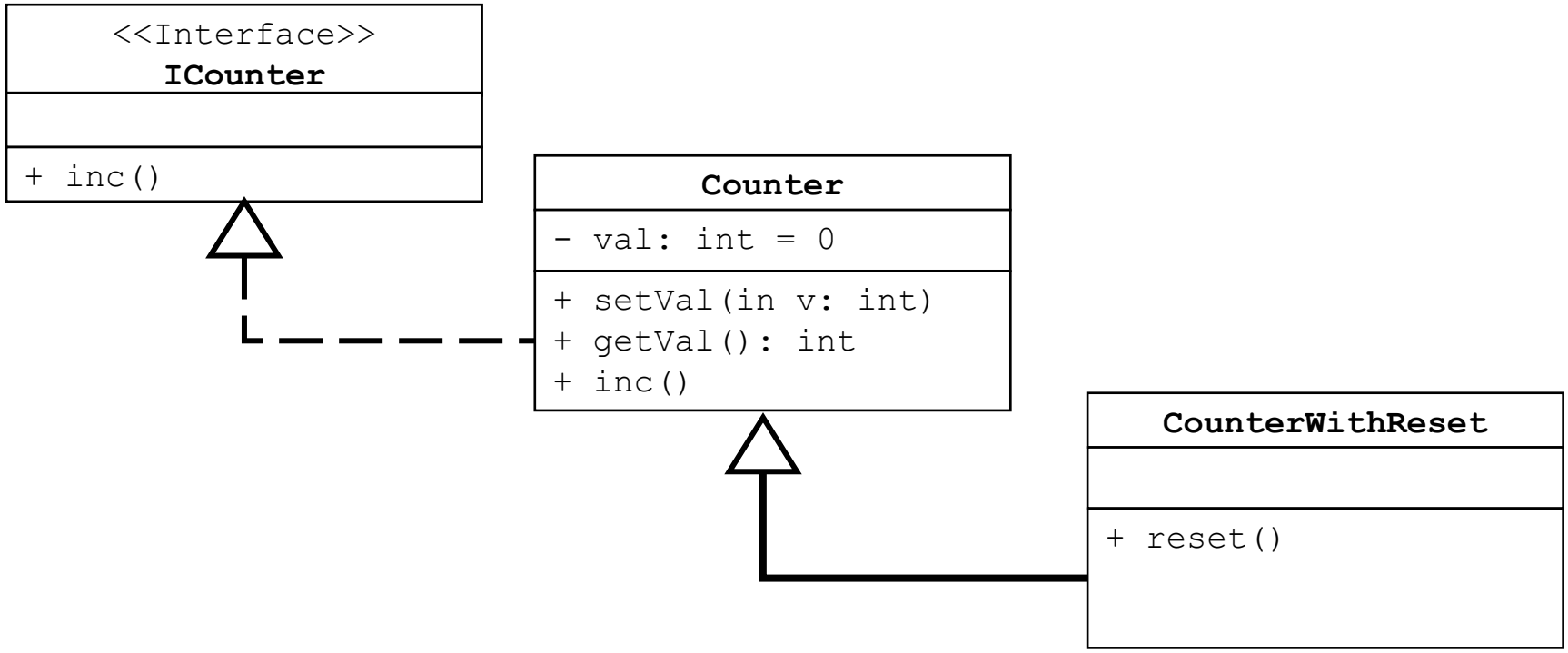


# Inheritance

Basic principles

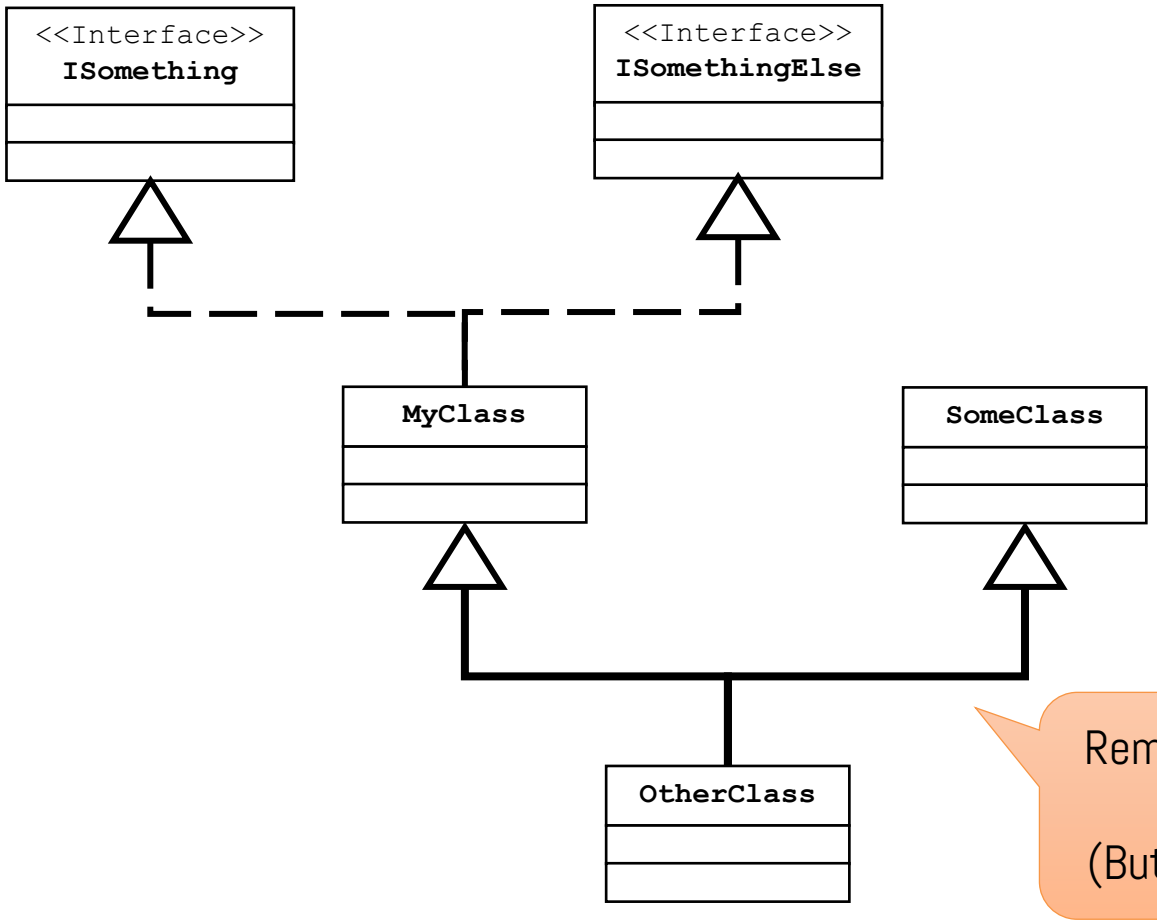
- Properties in super-classes
- We do not write it (unless w
- Visibility rules apply

| Super | Sub |
|---|---|
| Public | Public |
| Private | Not accessible by subclasses |
| Protected | Not accessible by other classes, but only by sub-classes |



# Multiple inheritance

- We can create trees or graphs (res: simple and multiple inheritance)

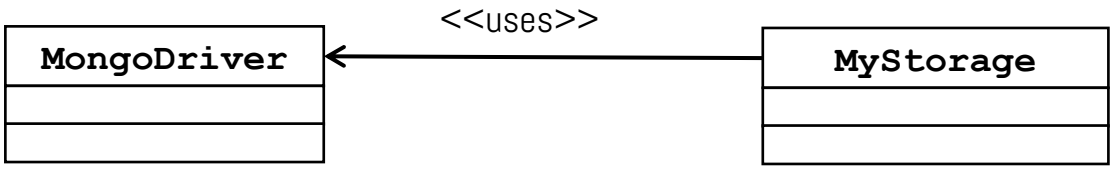



Remember this is not legal in Java, nor in C#!
(But it is in C++ and Python)

# Dependency

Semantic relations: one element requires another element

- Models a “client-server” relation
- Dotted line + stereotype *“<<uses>>”* (which can be omitted)



# Template classes

Some properties, or ret vals in classes that are generic

- I.e., not specified as we create the class
- We specify them when we create the object
- Useful especially for data structures

Featured in every OO-language with static typing

- Java and C#: `generics`
- C++: `templates`

JS & Python have dynamic typing

- Class properties are simply implemented as dictionaries
- Did you ever notice this?

# Templates in Java

- C# syntax is nearly identical

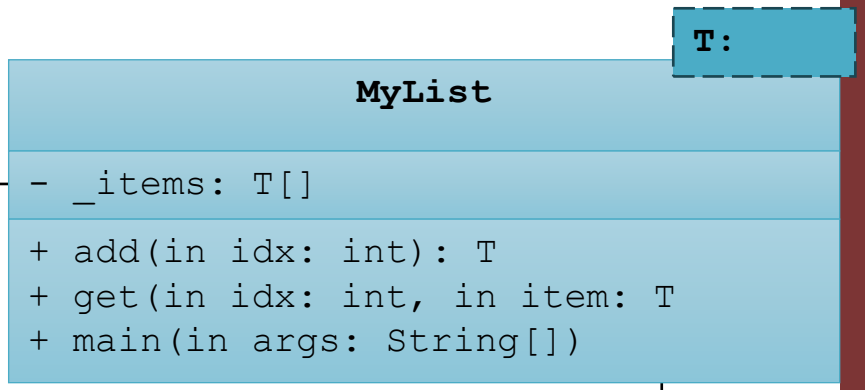
```
public class MyList<T> {
  private []T _items;
  public T add(int idx) {
    return this._items[idx];
  }
  public void get(int idx, T item) {
    this._items[idx] = item;
  }


  public static void main(String args[]){
    // Create a list for Strings
    MyList<String> list1 = new MyList<String>();
    list1.add(0, "Alessandro Del Piero");

    // Create a list for Integers
    MyList<Integer> list12 = new MyList<Integer>();
    list2.add(0, 10);
  }
}
```

# Templates in UML

- A dotted rectangle, on top-left of the class

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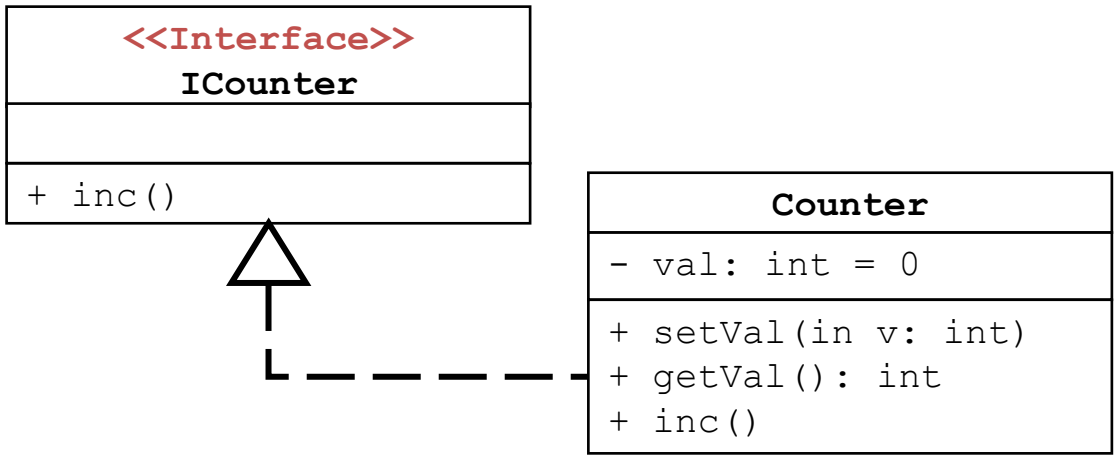
```

# Stereotypes

Extend notation with custom concepts

- E.g., `<<Interface>>`
- Each class can have at most 1 stereotype
- Partly already saw

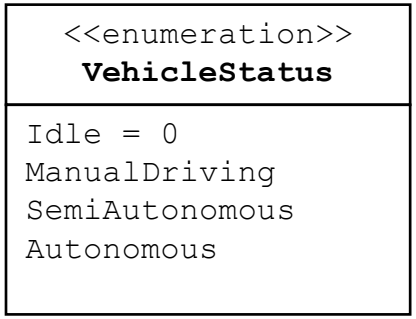


# There are even more notations!

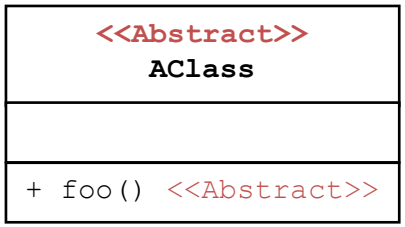
Won't see them here, they simply are too many

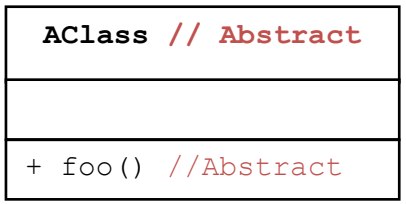
Few relevant

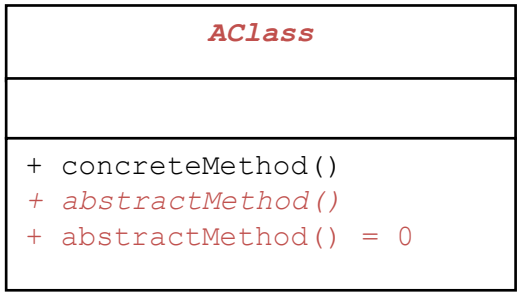
- Enums have the stereotype `<<enumeration>>`
- Active classes have double vertical borders
  - Classes with their own execution flow
- Abstract classes are a mess!
  - Everyone uses their notation
  - Classes that are only partly implemented
  - Not implemented methods are, in turn, called Abstract methods







# Object diagrams

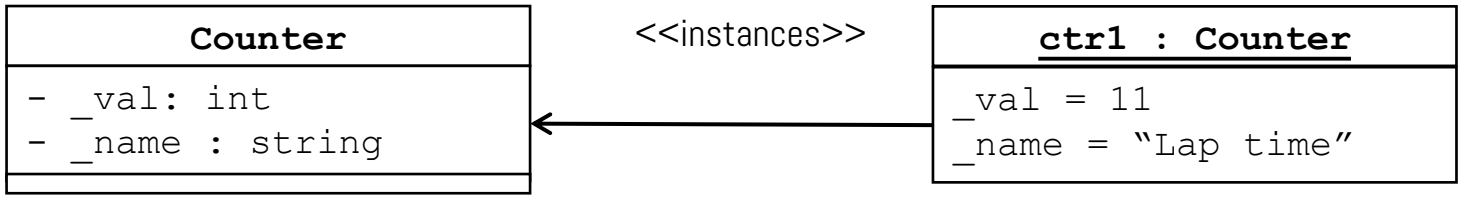
# Objects un UML

Instances of classes

- At run-time, they store the status of given (atomic) entities of our model/representation
  - But not statuic properties…do you remember the difference?
- And…the methods to access to data
- At least, they give us the chance to do so…

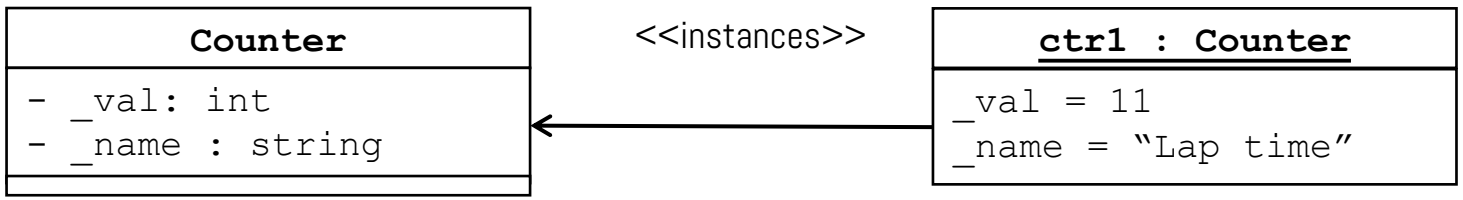
Notation is similar to the class diagram

- Also here, language-specific notations/conventions might apply
- Underlined



# Objects in UML

Find the difference

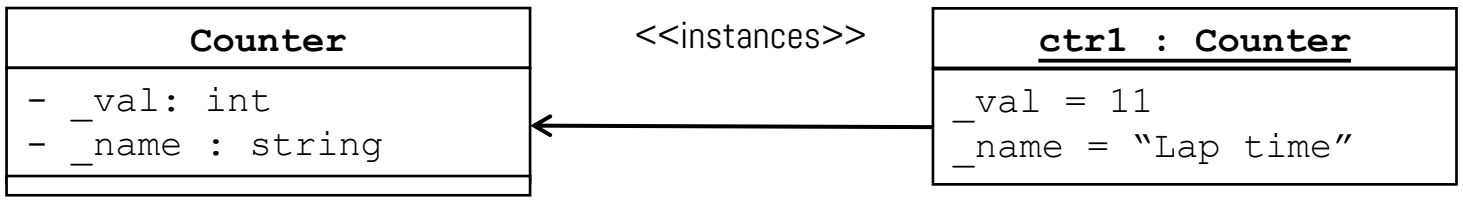


# Objects in UML

Find the difference

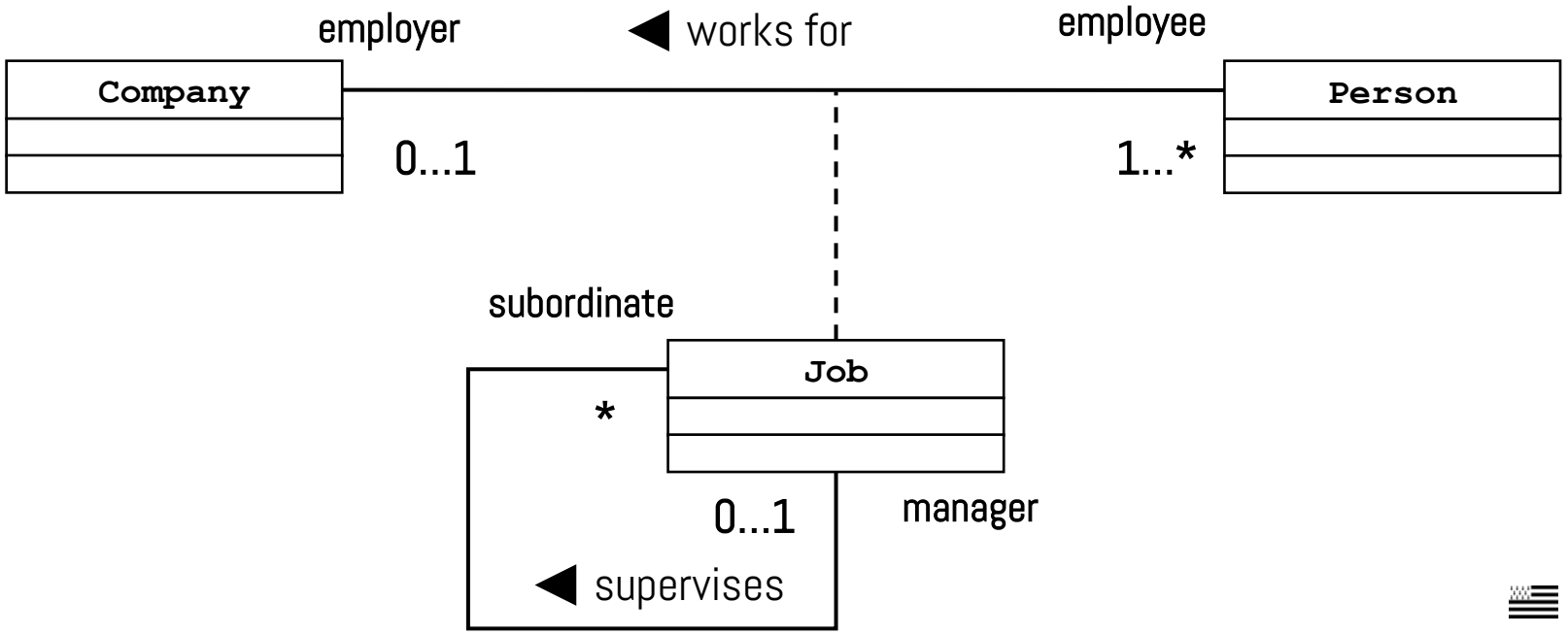
Static

Dynamic



# Relations between objects

› More or less the same than the ones between classes



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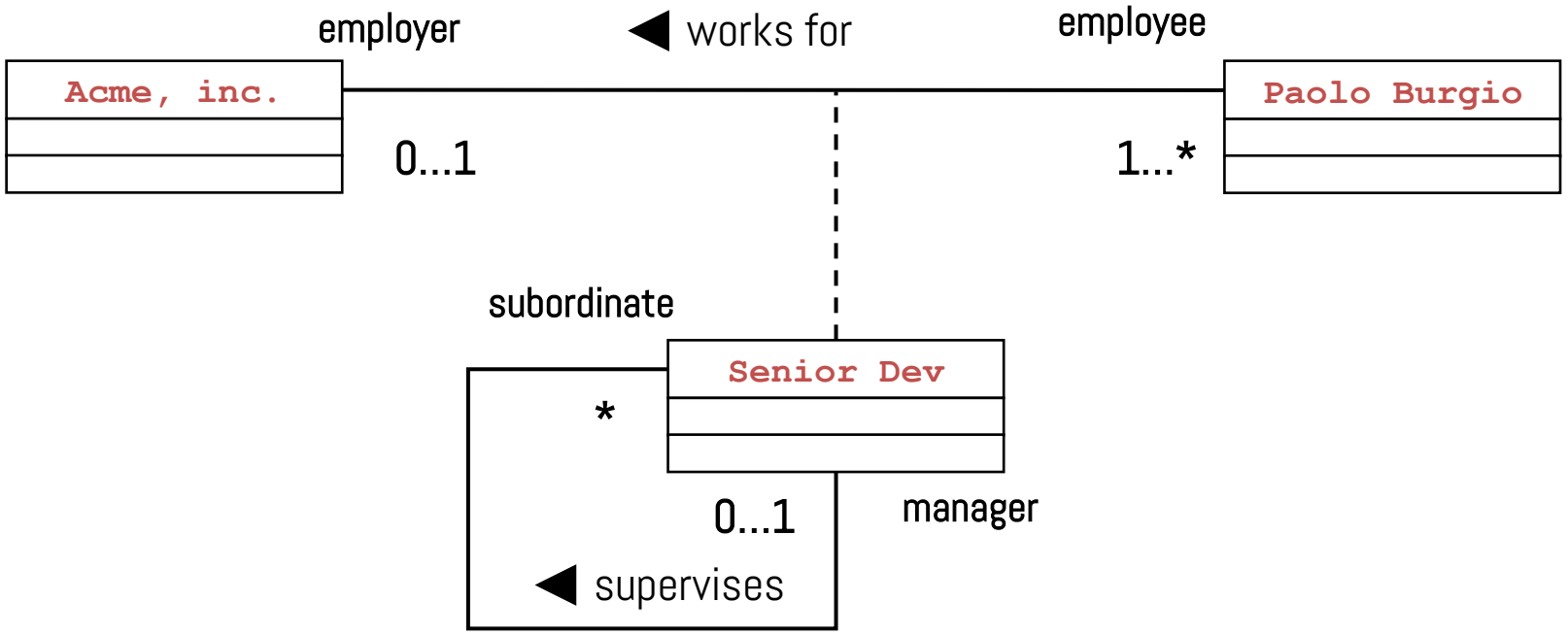


# Package diagrams

# What is a “package”

…ok, we are experts in Java..

- We can **group** our entities (i.e., classes) to structure our code
- Follows up by *divide-et-impera*

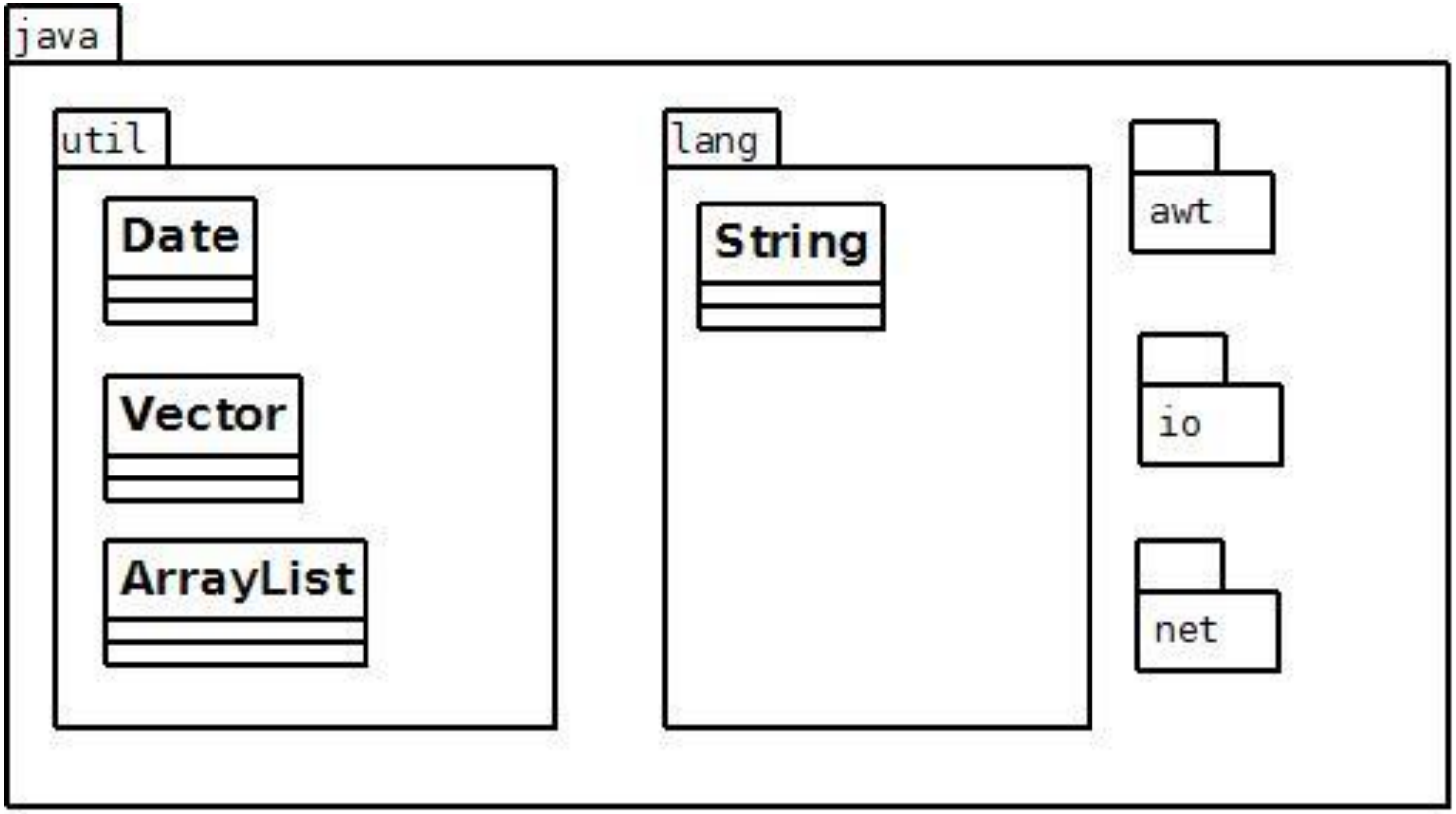
This is not so simple as it seems!

- Which classes do we group togetner? What are our “semantic boundaries”
- Do we group them by functionality?
- This is a design choice

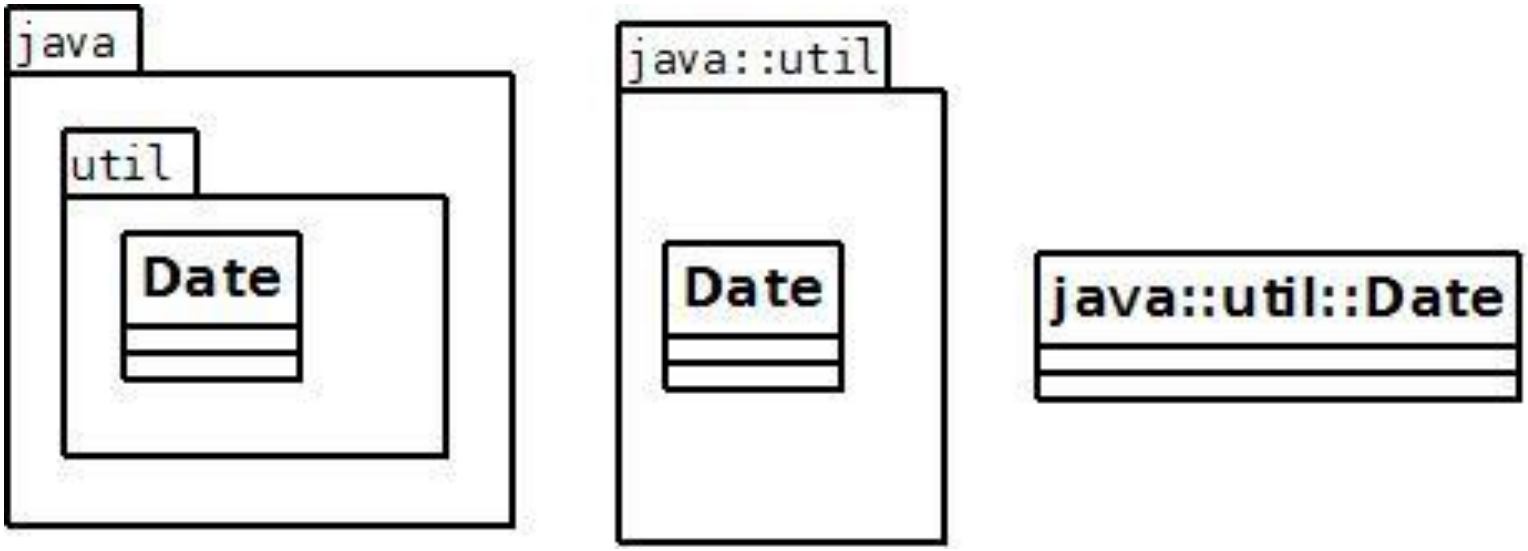
Practical example

- Java is "nice at us", as it forces us mapping packages on folders and sub-folders
- C# gives us more freedom…but also more responsibilities

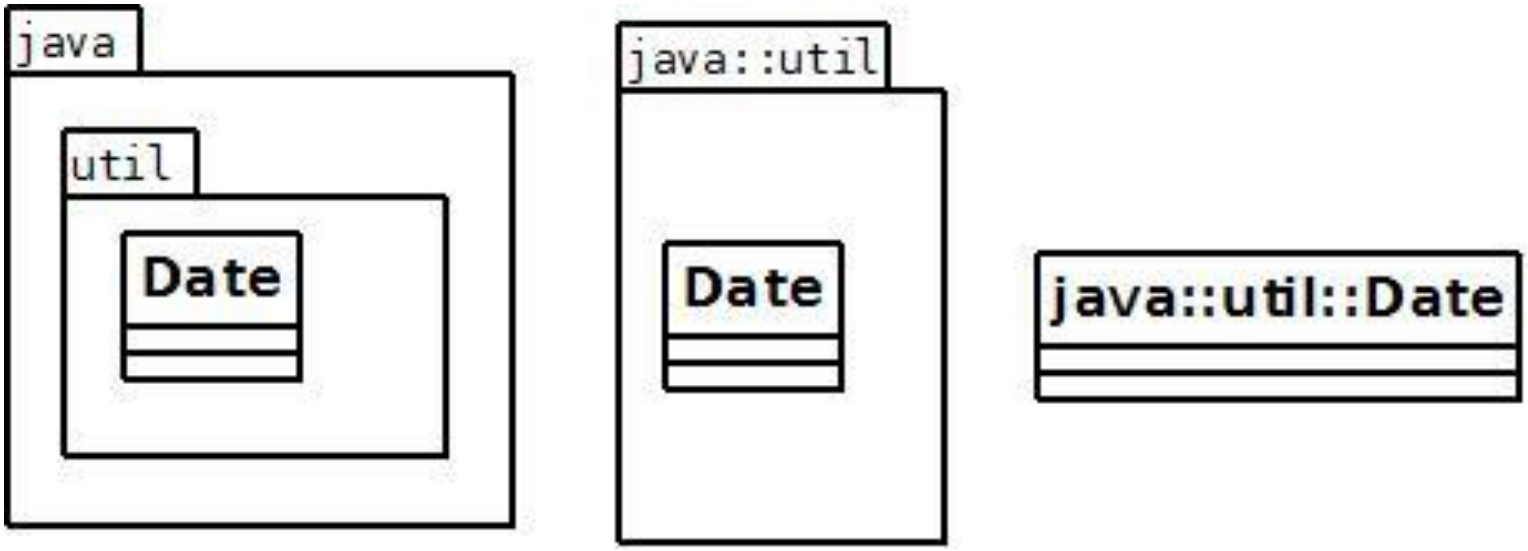
# Practical example in Java



# Nested packages, and class diagram



# Visibility recap

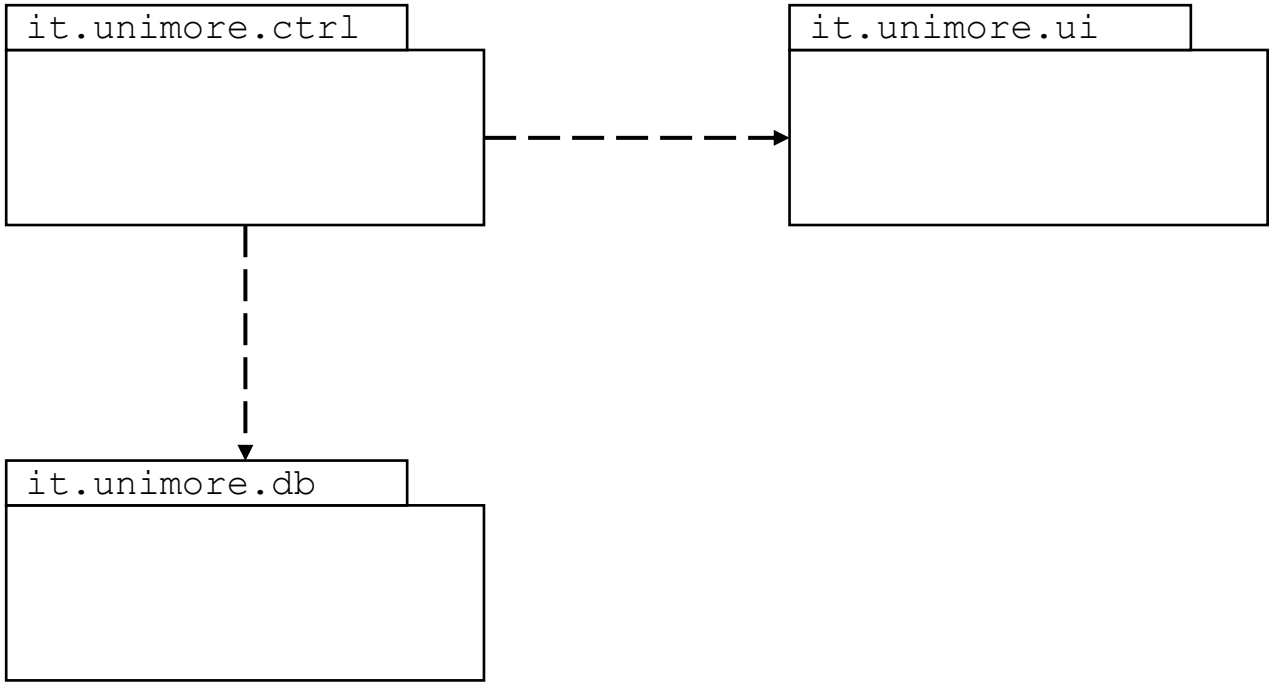



- There is only one "`util`" package within the "`java`" package
- There is only one "`Date`" class within the "`java::util`" package
- There is only one "`java:util:Date`" class

# Dependencies between packages

Dotted lines

- <<uses>> (default, omitted)
- Here, MVC as an example



# Dependencies between packages

Usage

- `<<uses>>` (default)
- Client-server relation between packages

Import

- `<<imports>>`
- Provider package namespace becomes par of client package namespace

Access

- `<<accesses>>`
- Elements from client package can access elements of provider package
- E.g., `friend` classes

- Recap: these are **not** transitive

# Recap (...?) Friend classes

Methods from friend class can access private fields and member of target class

- Target class explicitly declares this
- (...yes, it's a design pattern...)
- Disclaimer:**they only exists in C++**

# Recap (...?) Friend classes

```
#include <iostream>
using namespace std;

class Goo
{
  private:
    int private_variable;
    public: Goo() { private_variable = 10; }

    // friend class declaration
    friend class Foo;
};

class Foo
{
  public:
    void display(Goo& t)
    {
      cout << "The value of Private Variable = "
           << t.private_variable << endl;
    }
};

int main()
{
  Goo g;
  Foo fri;
  fri.display(g);
   return 0;
}
```

# Visibility between packages

For elements (classes, class methods…) within packages

- \- for private
- \+ for public
- ~ for package
- # for protected (visible only to child packages)

# References

Course website

- http://hipert.unimore.it/people/paolob/pub/ProgSW/index.html

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