UML for code design

Paolo Burgio
paolo.burgio@unimore.it

UNIMORE
UNIVERSITÀ DEGLI STUDI DI
MODENA E REGGIO EMILIA

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)
- 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

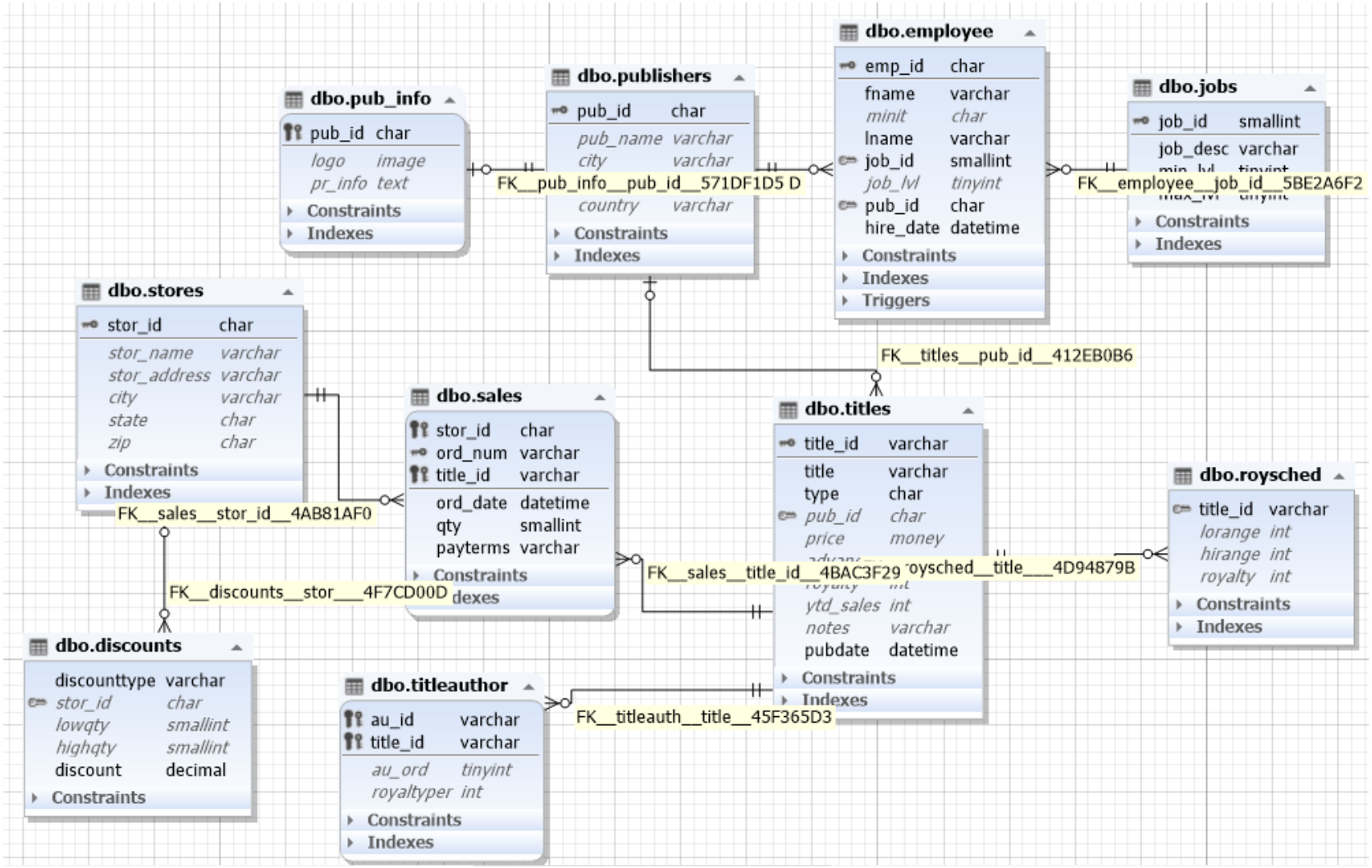
ER model from the SW engineering perspective

- 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



Class diagrams

Class diagrams

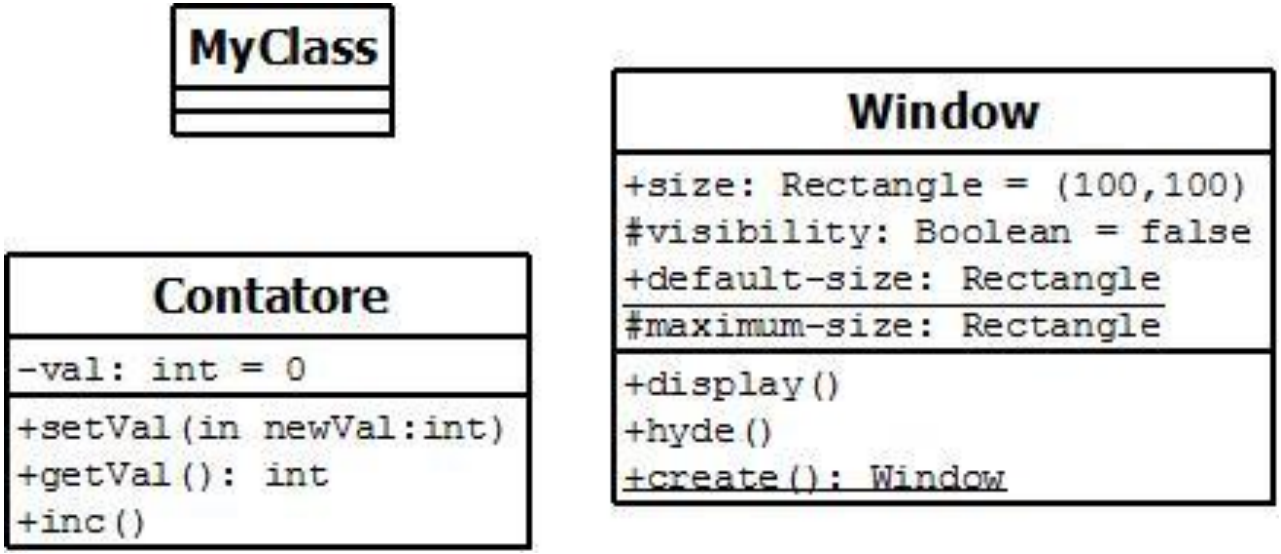
- A graph that (clearly) describes classes/interfaces and their relations by means of nodes and arcs
- Can be used to group elements within packages, or subsystems
- Used to model the static behavior of our system (i.e., classes), something that we can define at compile time

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 entities
- *Philosophical pills: this breaks **S**OLID…we will see it later*

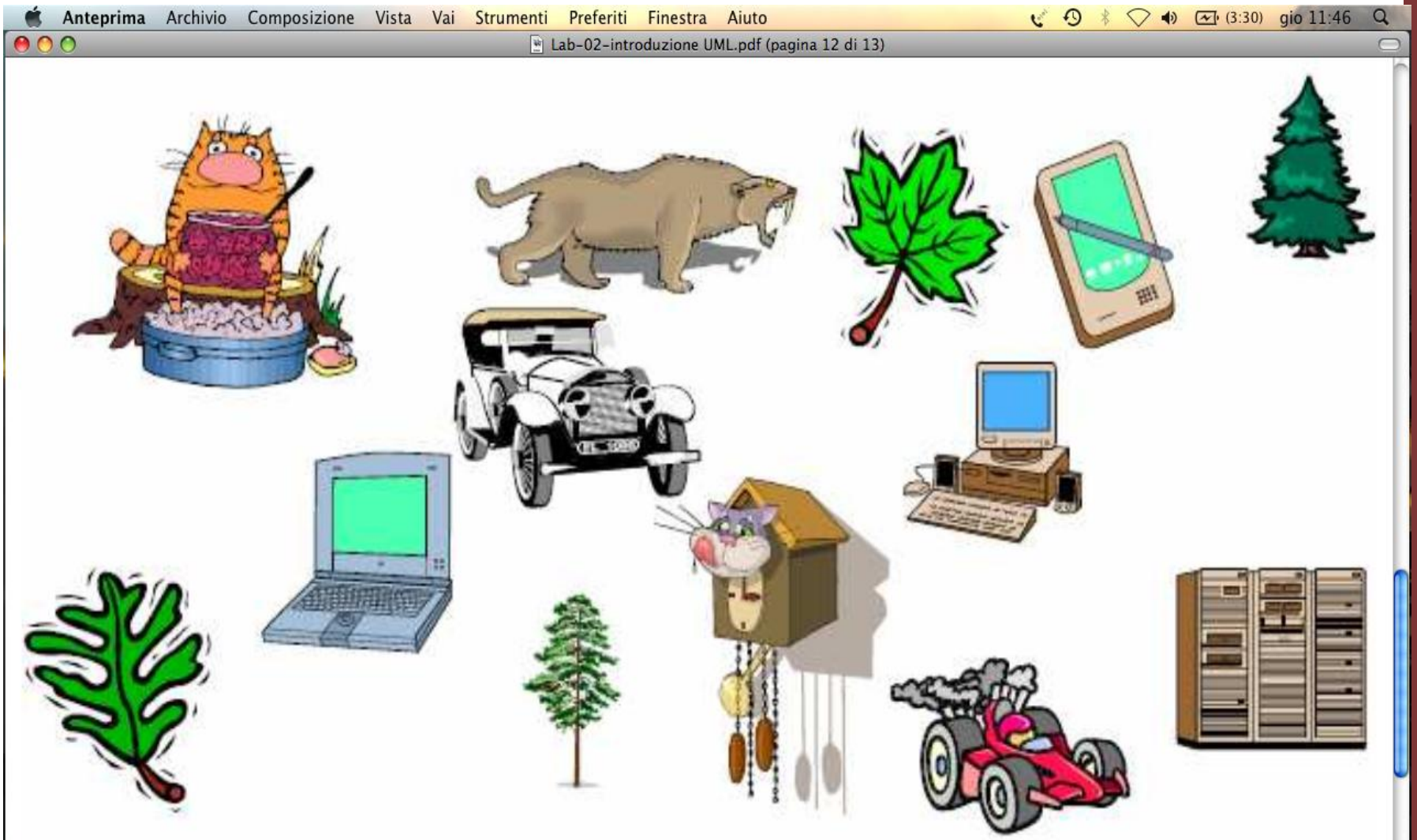
What is an object?

- 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?



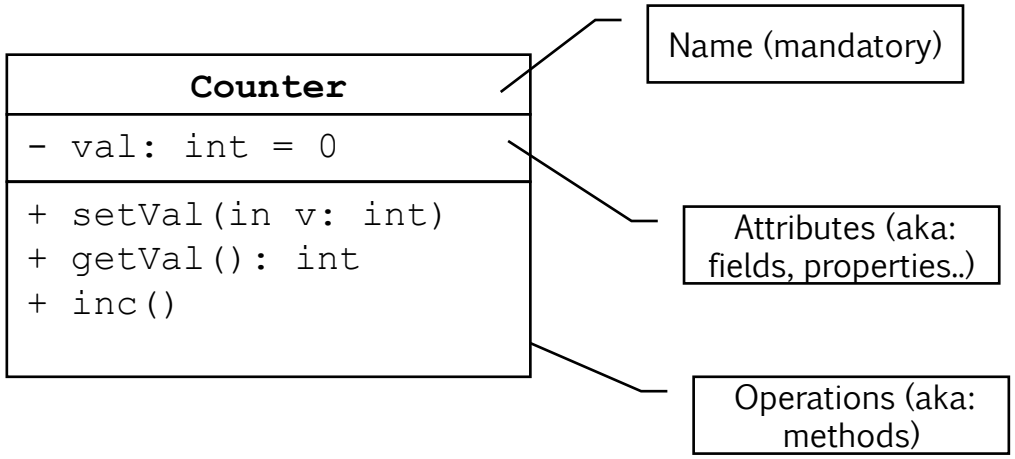
› We are forced to identify a proper abstraction level!

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)

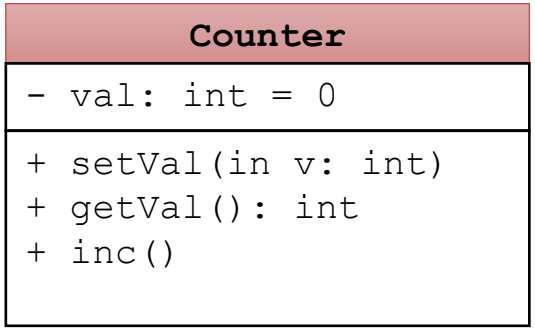


Name

A string of text

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

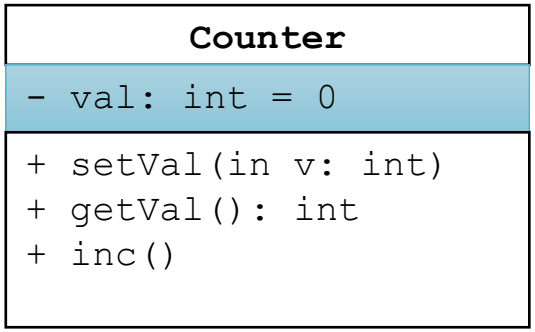
- Non-ambiguous



Attributes

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

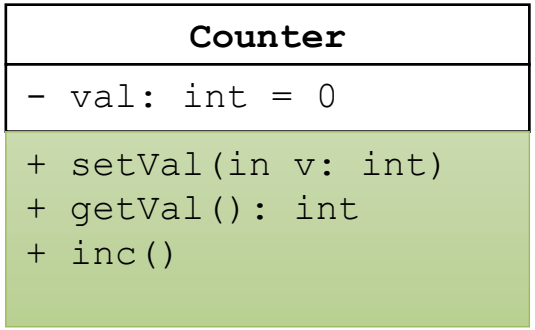
- Name is mandatory
- Visibility
  - **-** for private
  - **+** for public
  - **~** for package
  - **#** for protected
- Cardinality `[n]` for arrays
- `Static` attributes are underlined



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

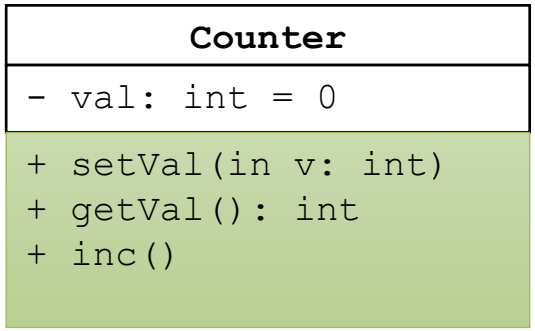
Queries

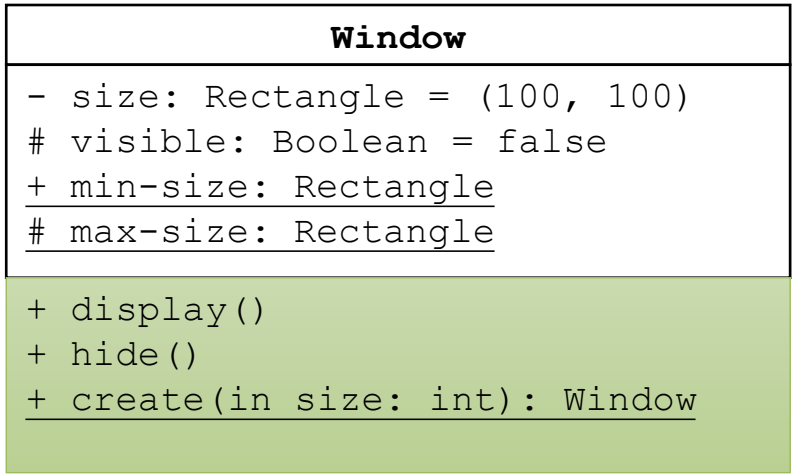
- (ex: Get-ters)
- Do not modify the status

Modifiers

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

Ctors to create new instances

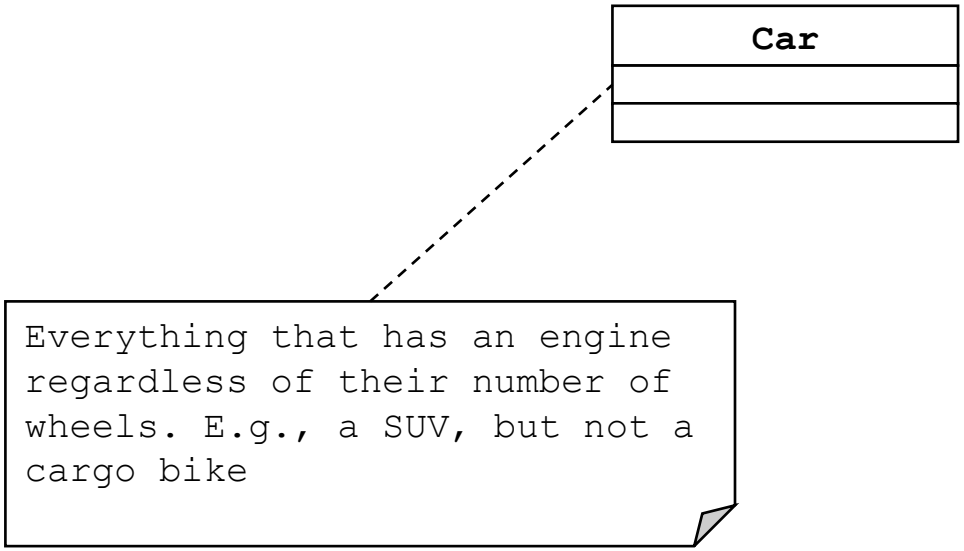




Adding notes and comments

Do not underestimate comments!!

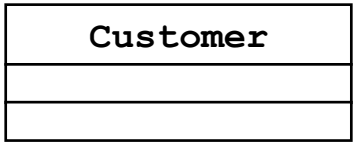
- We can automatically generate code (and their comments) by this
- We can automatically generate (technical) documentation by code comments
- We will have a dedicated lesson on that



Relation between classes

Associations

› Simple, aggregation, and composition

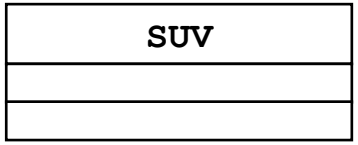


Dependency

› "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*

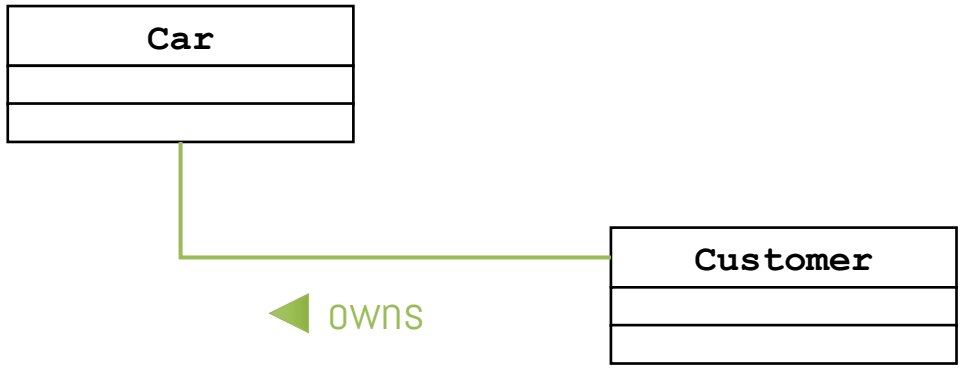
Features

› Name

› Roles

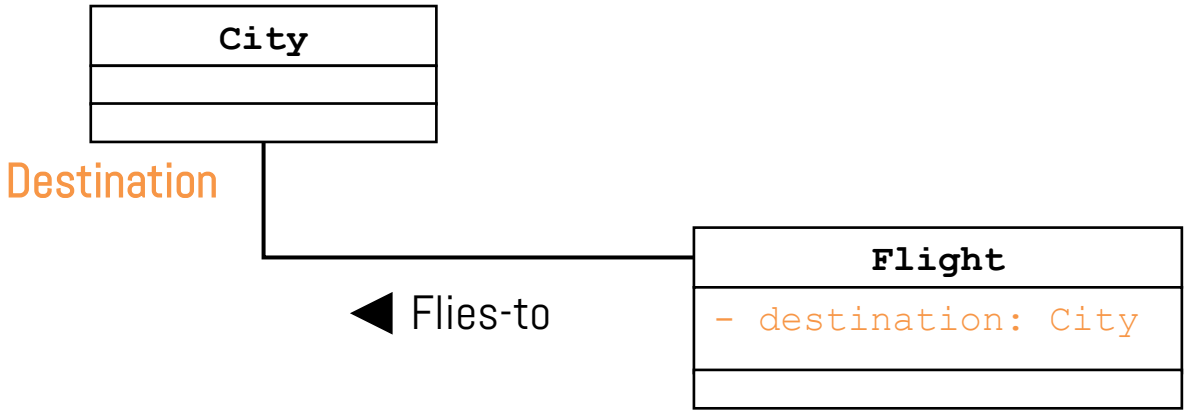
› Cardinality

› 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



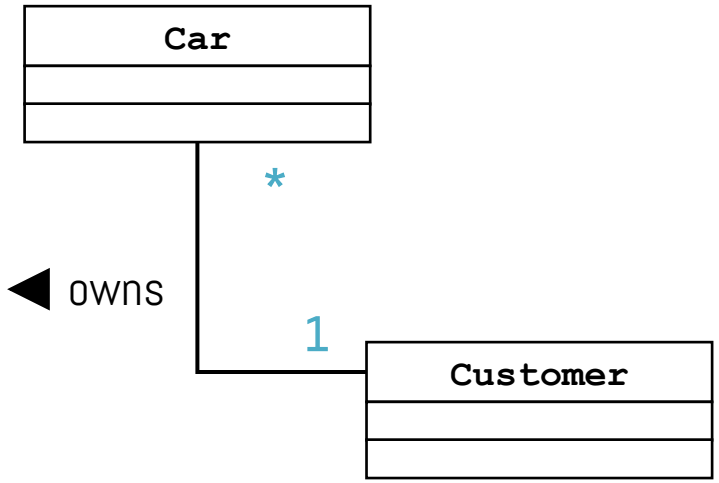
Association: cardinality

- 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"*)

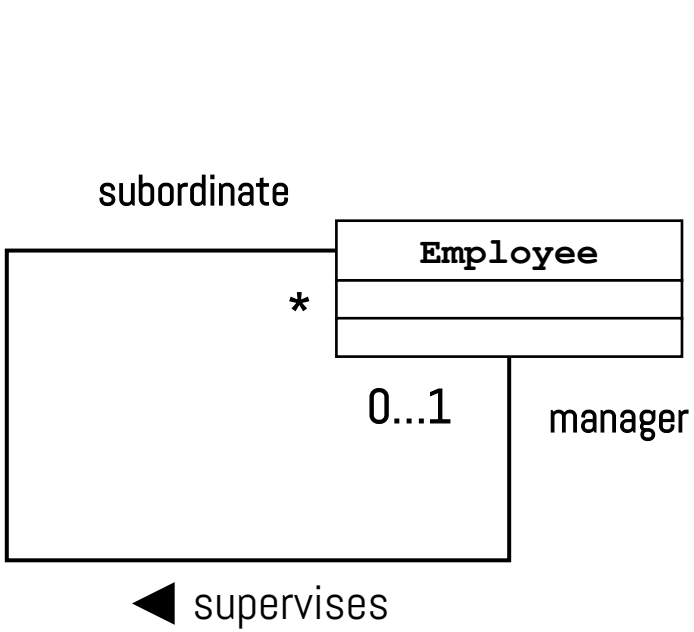


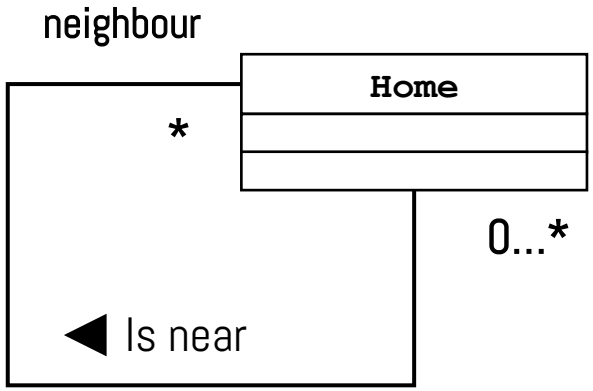
Notes

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

Association: reflective

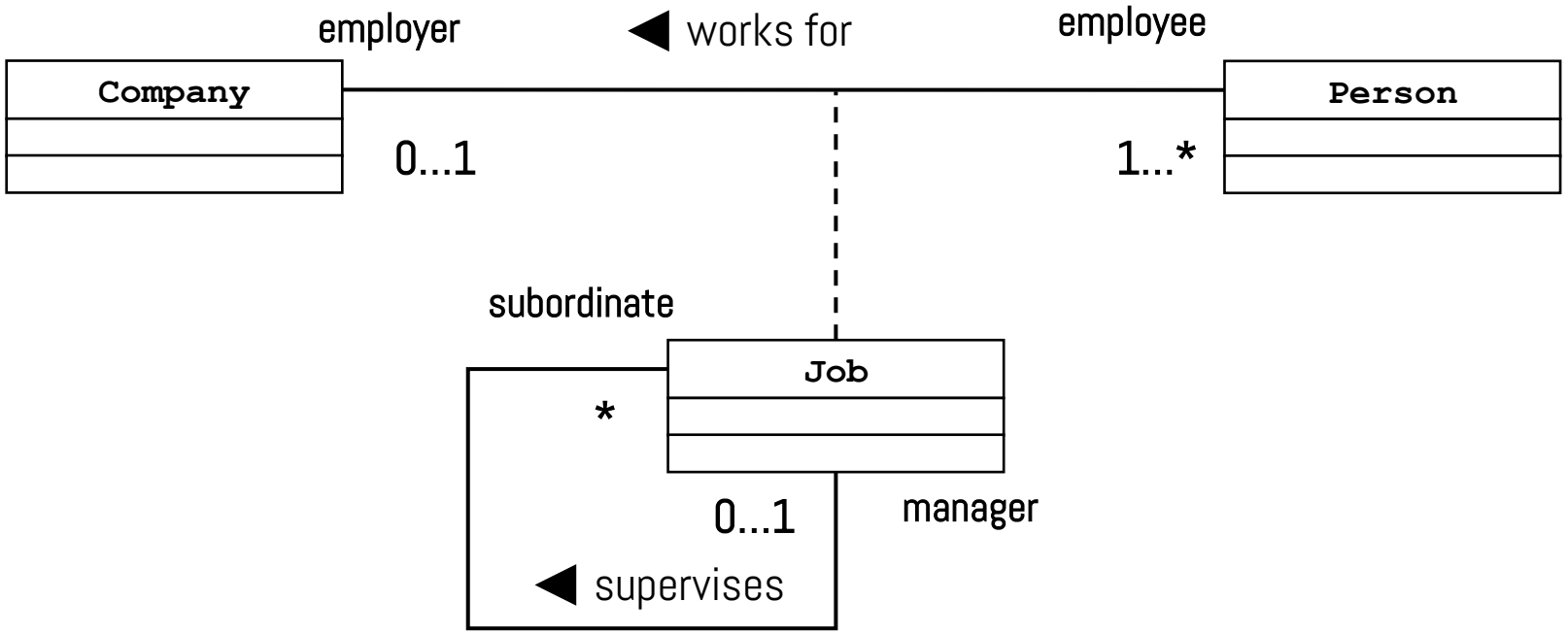
› In this case, roles are mandatory





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..

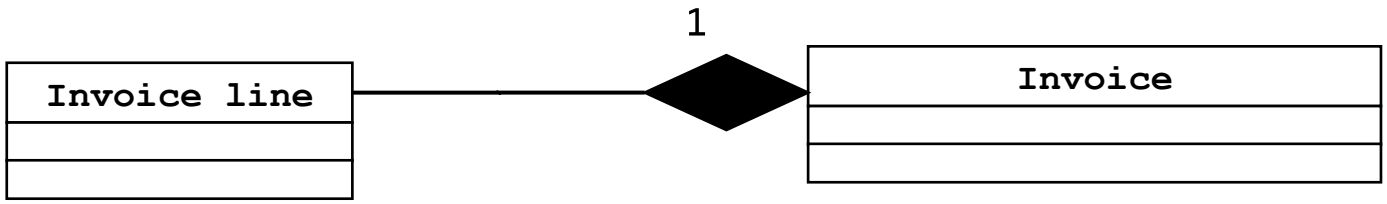
Modeled as **empy** rhombus (with cardinality) close to the containing class

Compositions

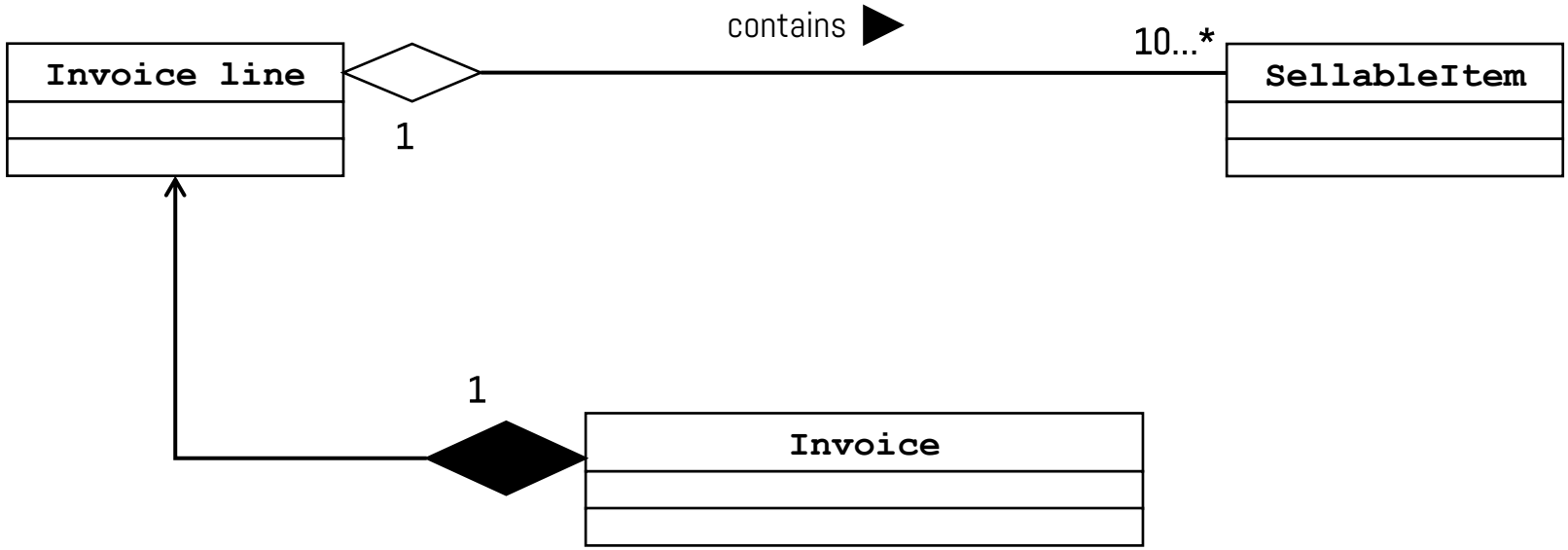
Are strong aggregations

- 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



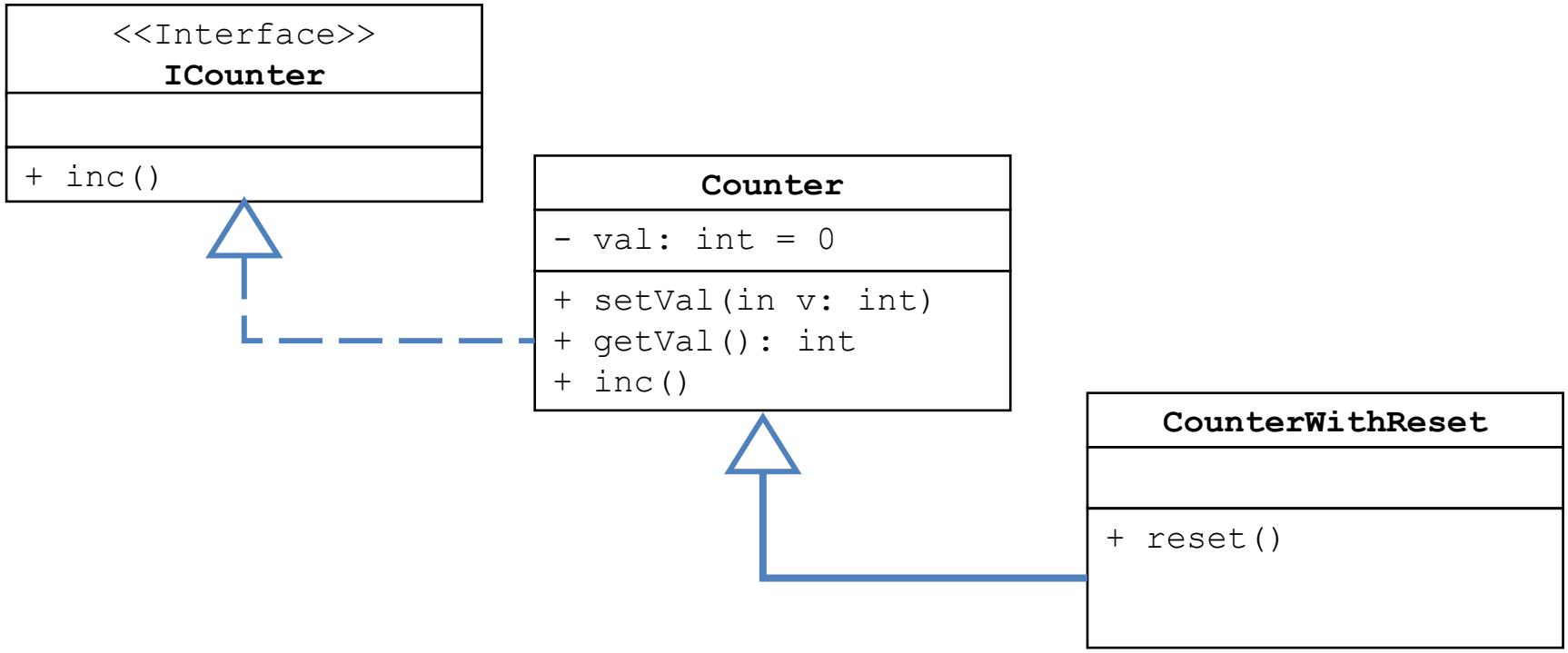
Compositions…and aggregations



Generalization/specialization

The typical relation in OOP

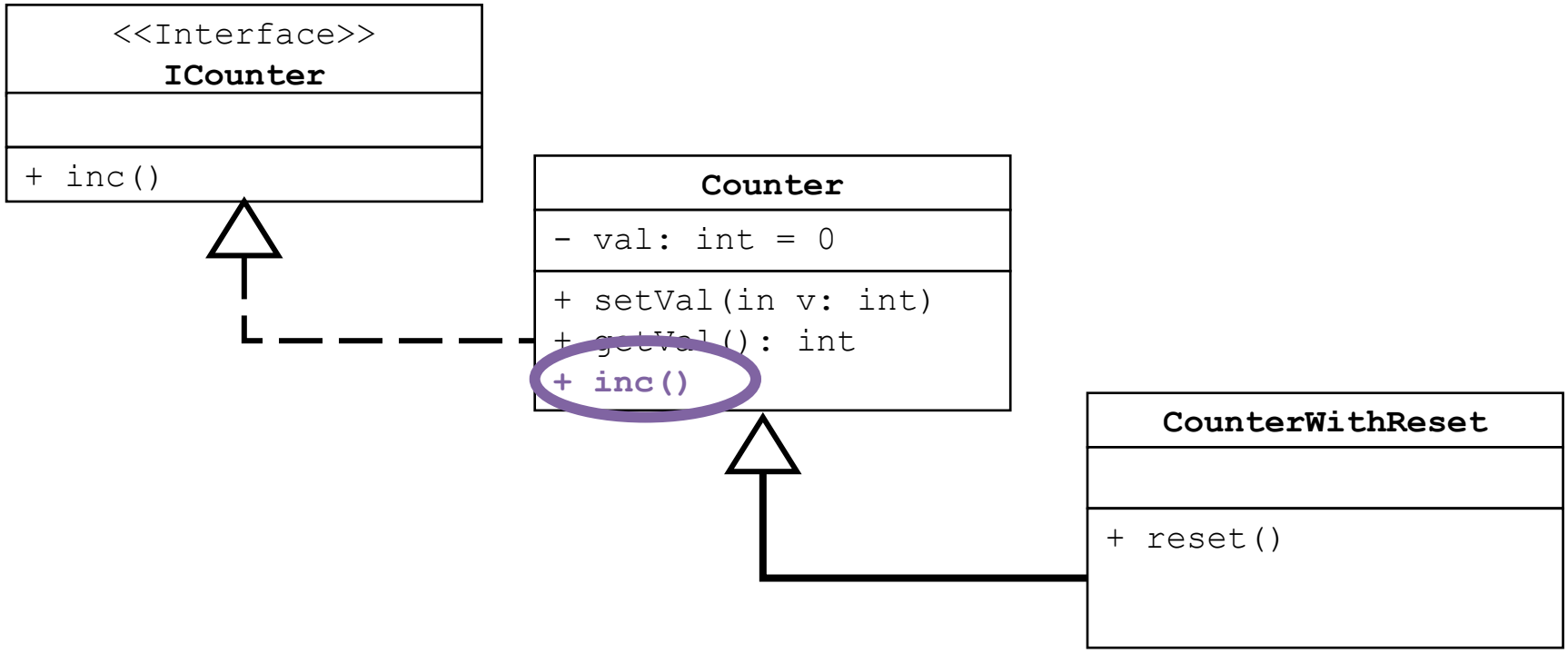
- Models "parent-child" relations, where child class(es) specify ("override ") the behavior
- Not limited to OO code!
- Dashed (subclass) or dotted (interfaces) line with empty arrow



Inheritance

Basic principles

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

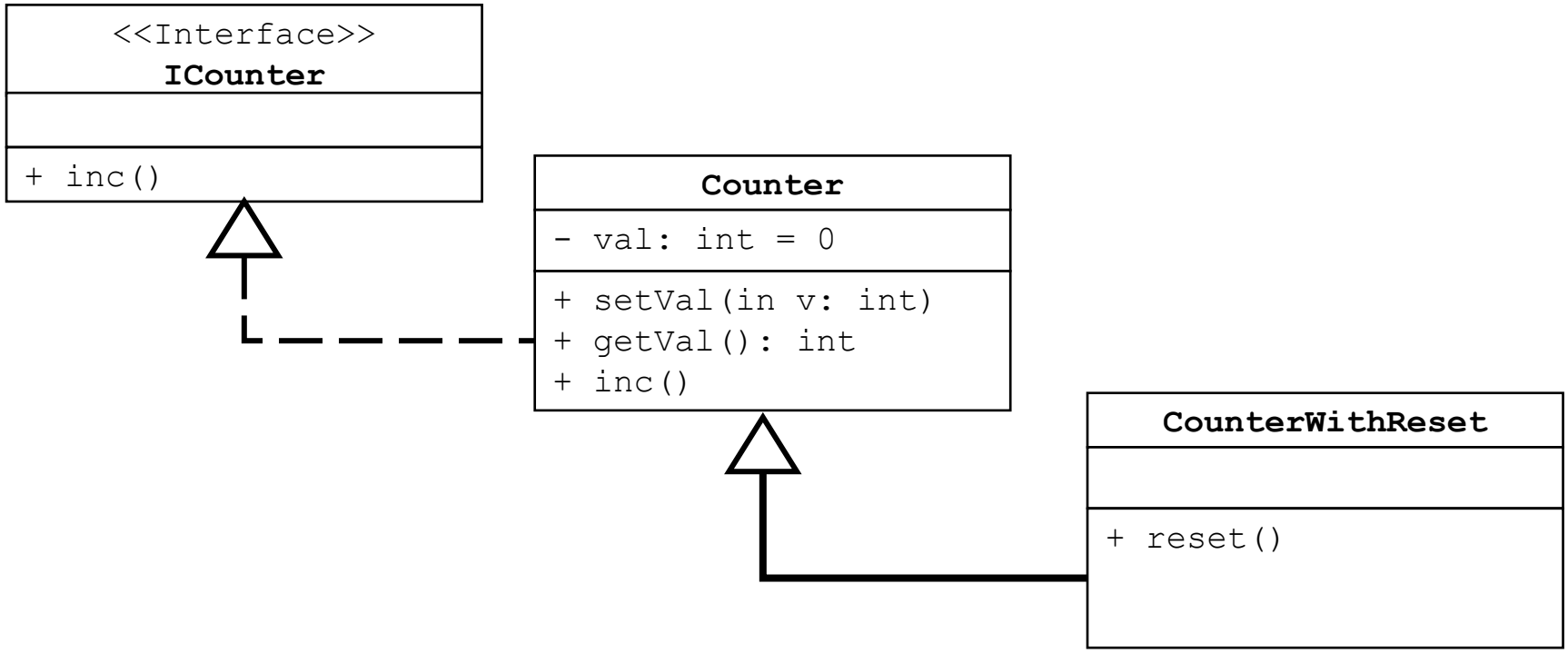


Inheritance

Basic principles

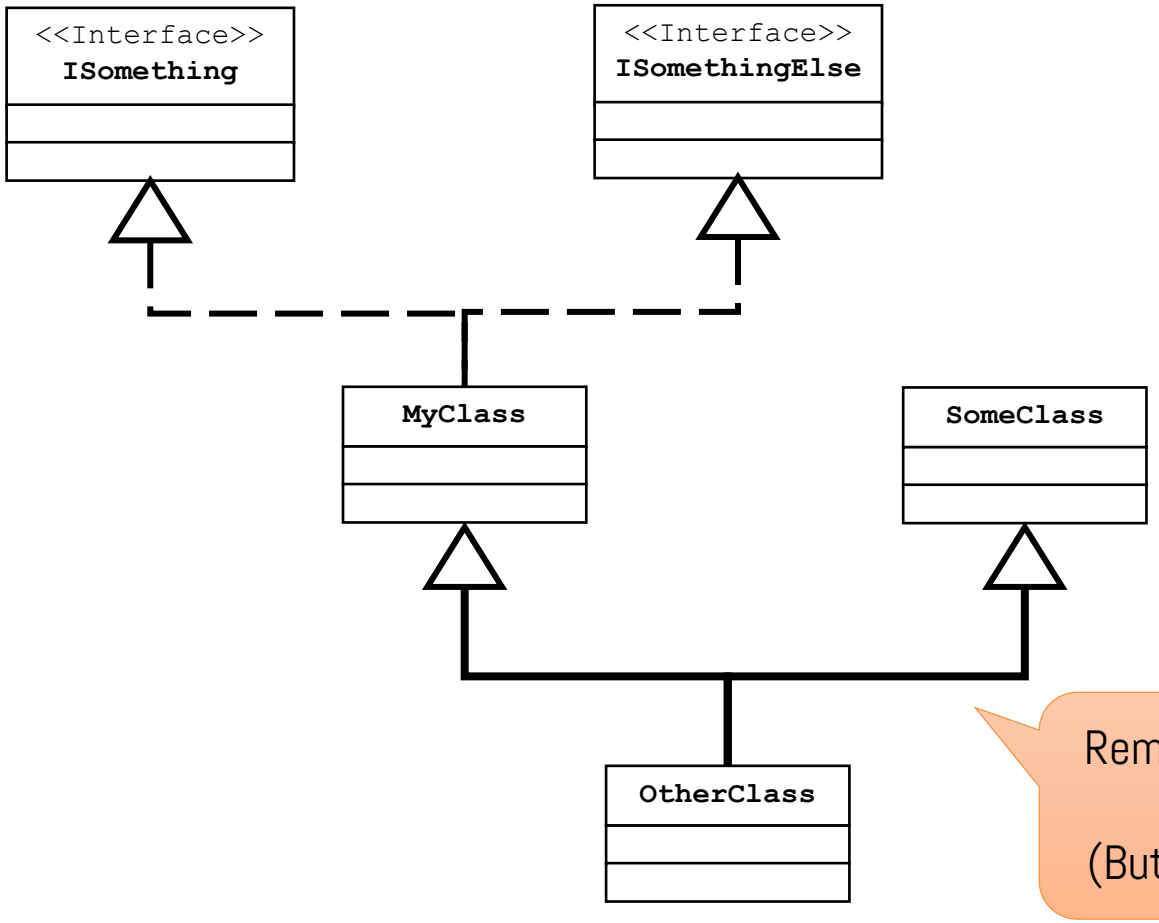
- Properties in super-classes are also in sub-classes
- We do not write it (unless we override it)
- Visibility rules apply

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)

The importance of interfaces

- Enable contract-based interaction between components (i.e., Classes)

```
///
/// Implement this to enable serialization
/// within a framework
///
public interface ISerializable {
  void serialize();
}

///
/// Basic counter functionality
///
public interface ICounter {
  void inc();
}

///
/// Implement this to enable printing
///
public interface IPrintable {
  void print();
}
```

```
void serializeAndSendViaSerial(ISerializable s) {
  Serial.send(s.serialize());
}

void foo(ICounter c) {
  c.inc();
}

void print(IPrintable obj) {
  obj.print();
}
```

```
public static void main() {
  // Counter class implements the three interfaces
  Counter c = new Counter();

  foo(c);

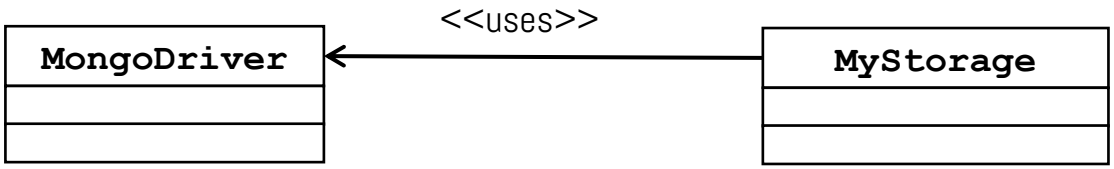
  serializeAndSendViaSerial(c);

  print(c);
}
```

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

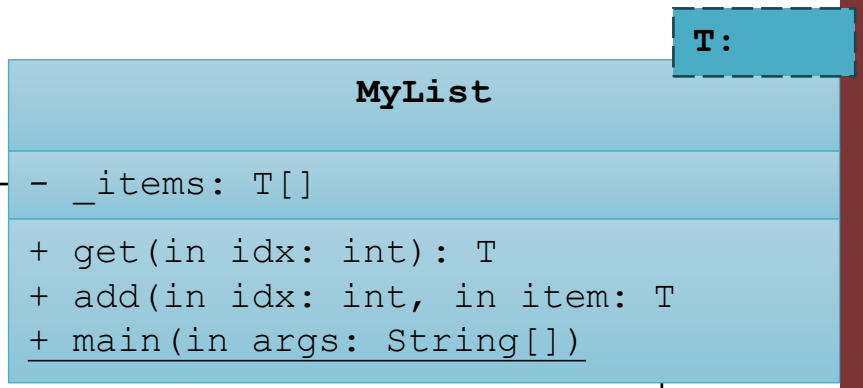
```
public class MyList<T> {
  private []T _items;
  public T get(int idx) {
    return this._items[idx];
  }
  public void add(int idx, T item) {
    this._items[idx] = item;
  }


  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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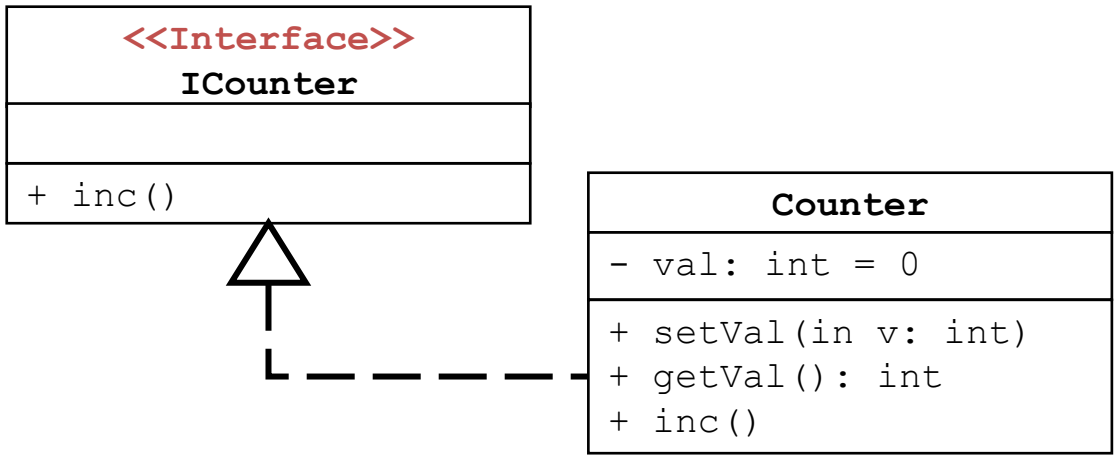
    list2.add(0, 10);
  }
}
```

Stereotypes

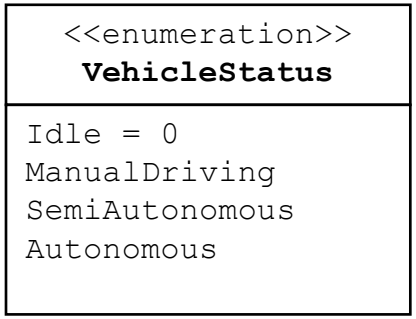
Extend notation with custom concepts

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



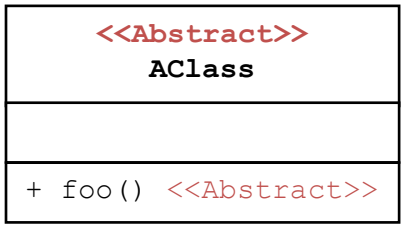
There are even more notations!

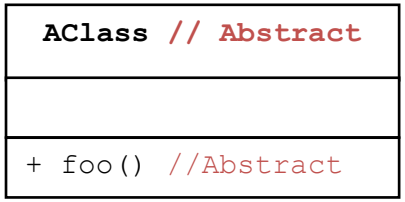
Won't see them here, they simply are too many

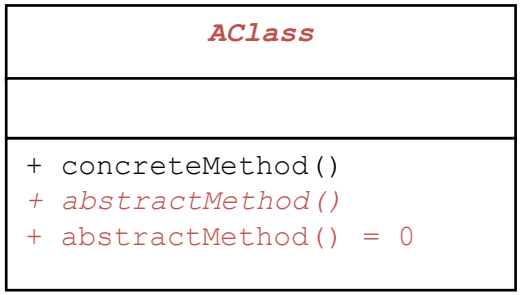


Few relevant

- 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

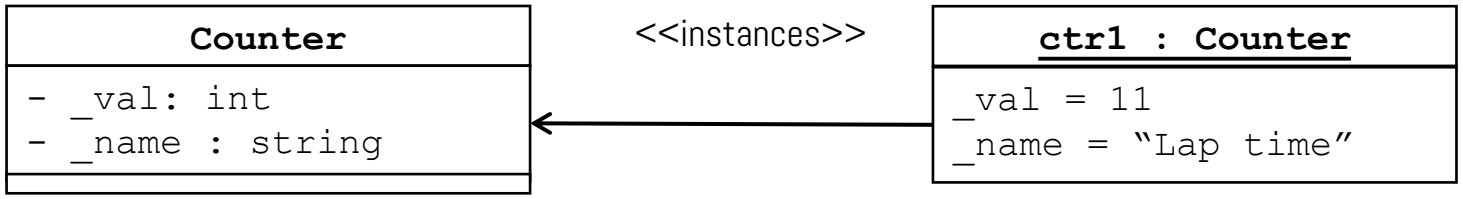
Objects un UML

Instances of classes

- At run-time, they store the status of given (atomic) entities of our model/representation
  - But not static 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

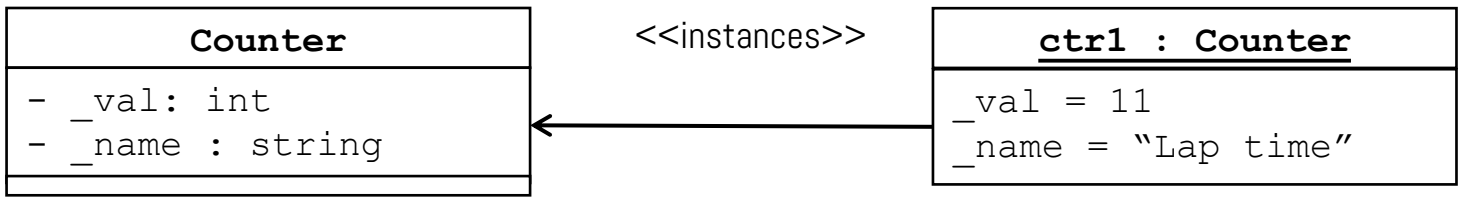


Objects in UML

Find the difference

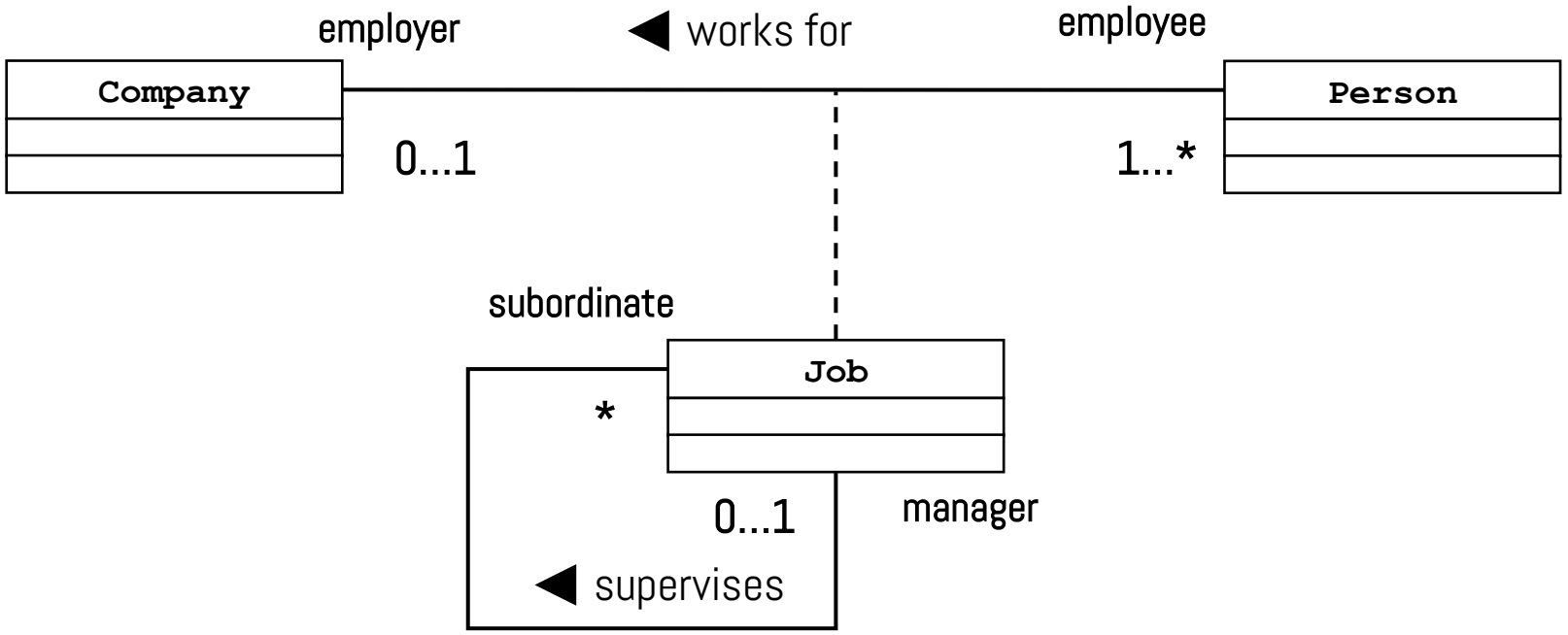
Static

Dynamic



Relations between objects

› More or less the same than the ones between classes



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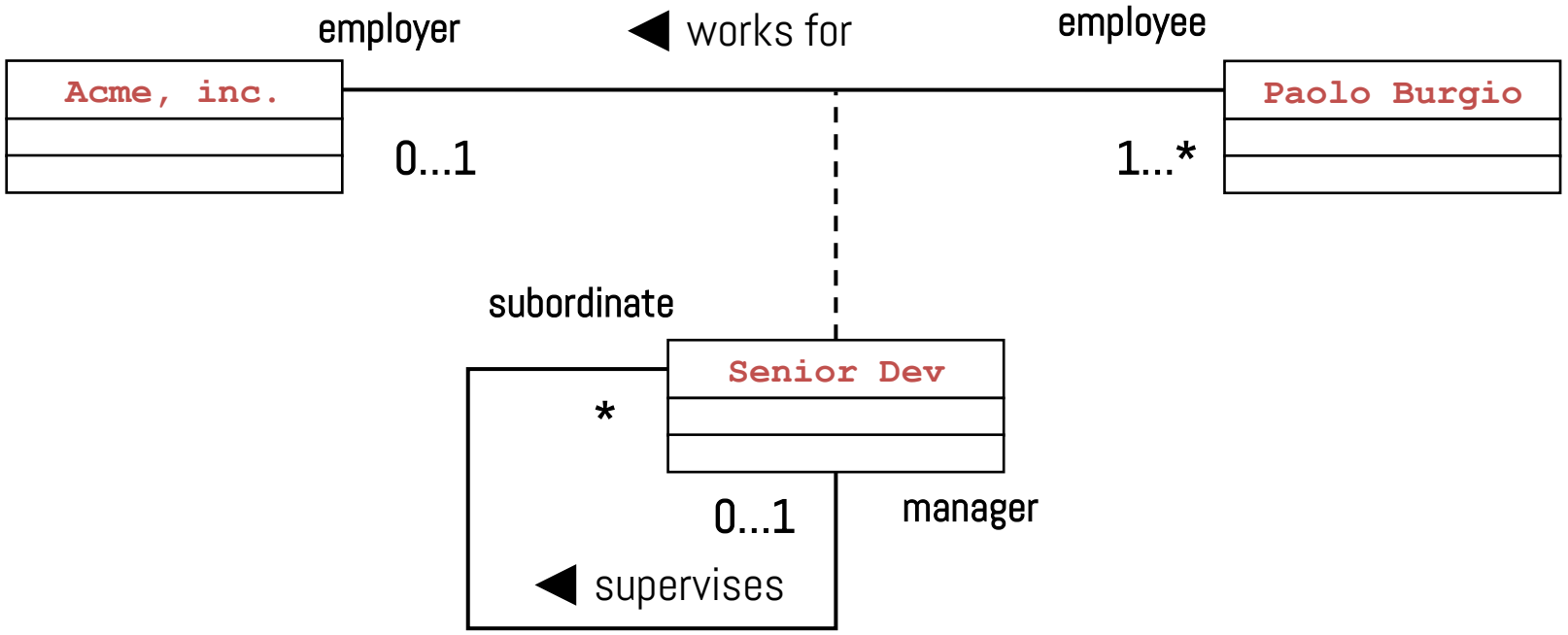


Package diagrams

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*

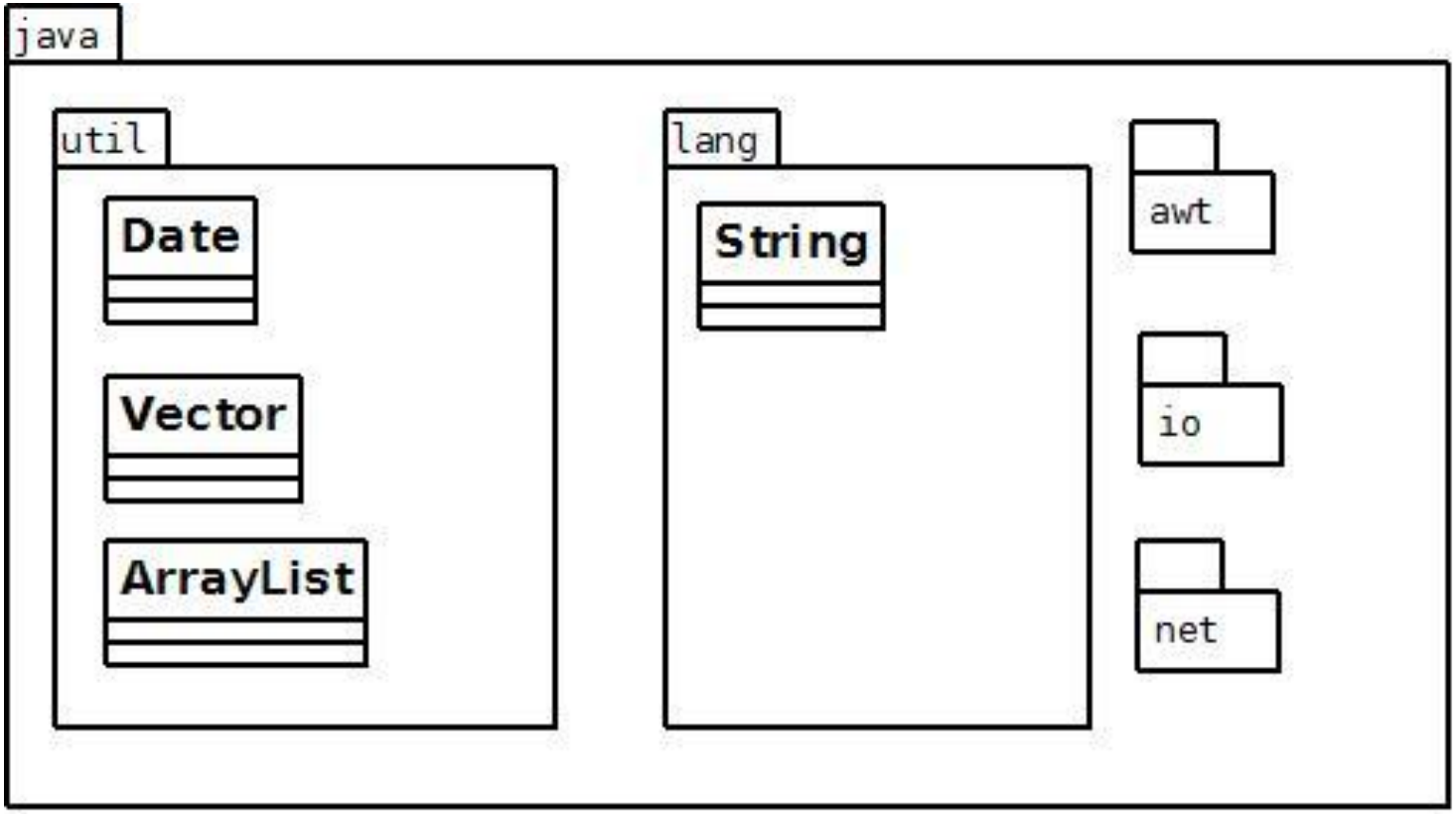
This is not so simple as it seems!

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

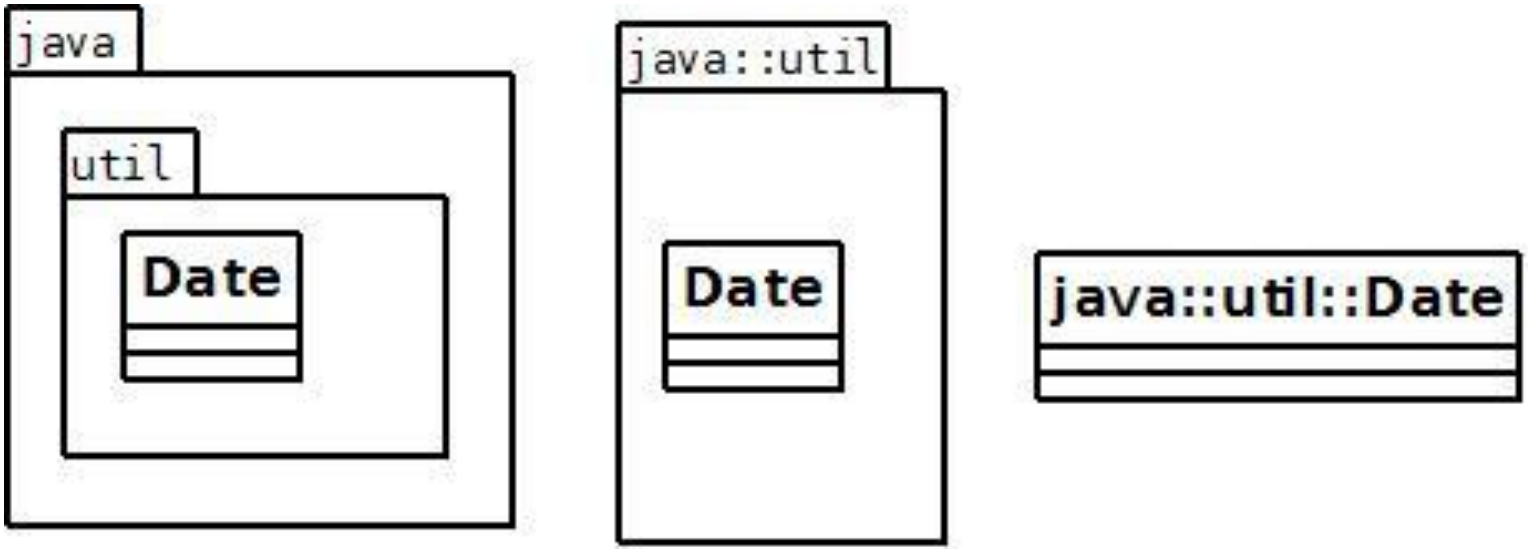
Practical example

- 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

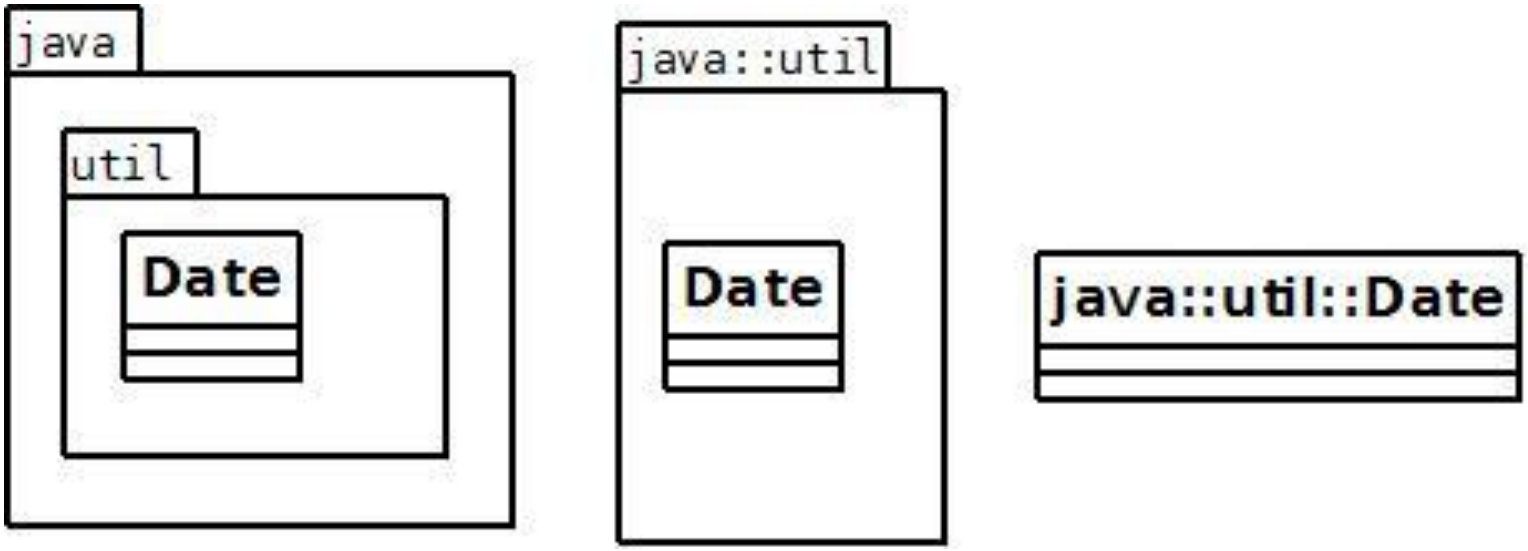
Practical example in Java



Nested packages, and class diagram



Visibility recap

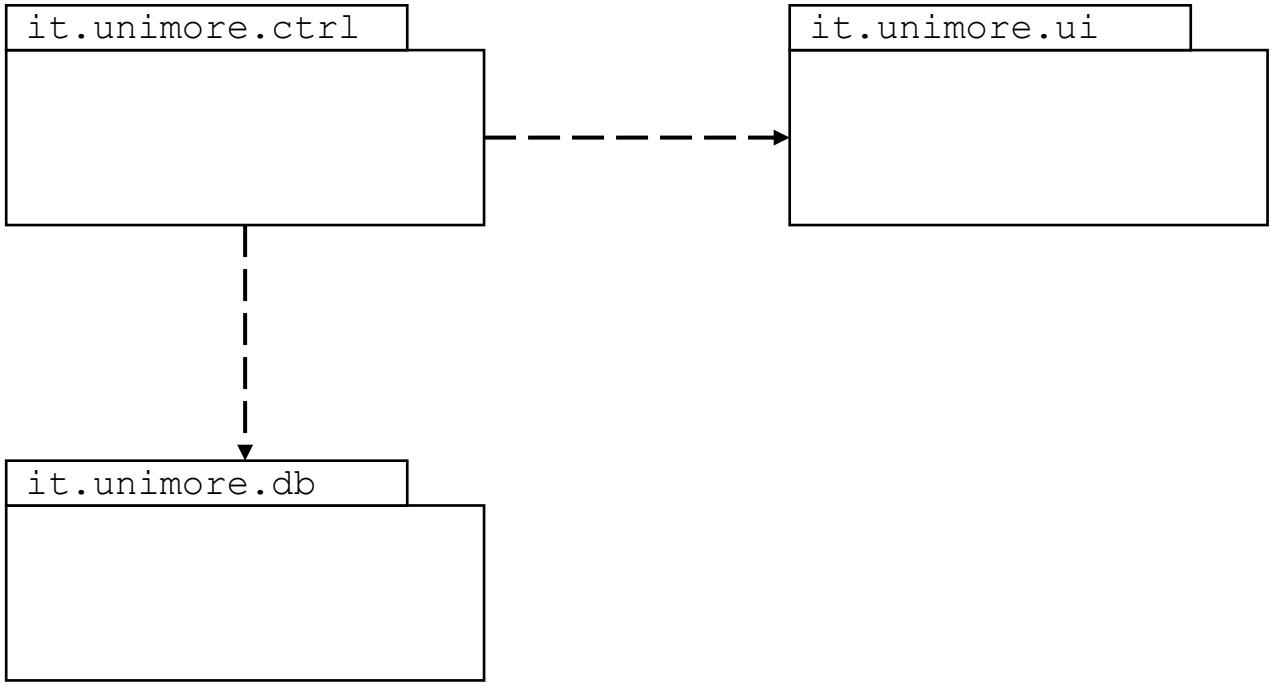


- There is only one "`util`" package within the "`java`" package
- There is only one "`Date`" class within the "`java::util`" package
- There is only one "`java::util::Date`" class

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 part 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

My contacts

- paolo.burgio@unimore.it
- http://hipert.mat.unimore.it/people/paolob/
- https://github.com/pburgio