SOFTWARE DESIGN

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MANAGEMENT ISSUES

Time & Location:

- See Schedule on www.ac.utcluj.ro
- Course files: moodle.cs.utcluj.ro

course enrollment key: **course_PS/SD2020**

group key: **grouP_30231** (adapt to your group #)

Grading:

- Project 20%
- Lab 20%
- Final Exam 60%

YOUR TEACHING ASSISTANTS (TA)

30231 – Cristian Chira	30239 – Paul Stanescu
30232 – Grigore Vlad	302310 – Timotei Dolean
30233 – Anca Iordan	30431 – Lucian Braescu
30234 – Anca Iordan	30432 – Mihai Visan
30235 – Daniel Ciugurean	30433 – Radu Tufisi
30236 – Samuel Dolean	30434 – Richard Ardelean
30237 – Anca Iordan	CSC – Maria Potolea
30238 – Anca Iordan	

LAB SESSIONS

- Are COMPULSORY
- Maximum 3 absences allowed (BUT should be caught up)
- Only one assignment/lab session can be presented
- You need to get a grade >= 5 for the lab and project to attend the final exam
- **Attend the lab sessions only when your group is scheduled**

RESEARCH

Research for Diploma projects

(Deep) Machine learning applied in

- Neuroscience ((Explainable)Network analysis, Information coding, Spike sorting and burst detection)
- Language representation and understanding (ex. chatbots)
- IoT Data Analysis (ex. failure prediction, user profiling)
- Learning robots (imitation learning, reinforcement learning)

PROJECT

- Decide
- If Research project

⇒Write an e-mail to any of {rodica.potolea@cs.utcluj.ro, mihaela.dinsoreanu@cs.utcluj.ro, camelia.lemnaru@cs.utcluj.ro} **by the end of the week (Sunday, 1st of March)** containing your name, group, relevant grades so far (i.e. Programming Techniques, Algorithms, etc.)

⇒We will get back to you with the next steps

WHAT DO YOU EXPECT FROM THIS COURSE?

Please feel encouraged to tell/e–mail me any ideas/suggestions/complaints…

REFERENCES [1]

Software Architectures

- Juval Lowy, Righting software, O'Reilly, 2020
- Ian Gorton, Essential Software Architecture, Springer, second ed. 2011.
- Taylor, R., Medvidovic, N., Dashofy, E., Software Architecture: Foundations, Theory, and Practice, 2010, Wiley.
- Len Bass, Paul Clements, Rick Kazman, Software Architecture in Practice, 3rd edition, 2013.
- David Patterson, Armando Fox, Engineering Long-Lasting Software: An Agile Approach Using SaaS and Cloud Computing, 2012
- Buschmann, Frank, Regine Meunier, Hans Rohnert, Peter Sornmerlad, and Michael Stal. 2001. *Pattern-oriented system architecture, volume 1: A system of patterns*. Hoboken, NJ: John Wiley & Sons. [POSA book]
- Fowler Martin, *Patterns of Enterprise Application Architecture,* Addison-Wesley Professional, 2002

REFERENCES [2]

Design Patterns

- E. Gamma, R. Helm, R. Johnson, and J. Vlissides. Design Patterns. AddisonWesley, 1995. [GoF]
- Craig Larman, *Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design and Iterative Development* (3rd Edition), Prentice Hall, 2004, ISBN: 0131489062

Courses

- B. Meyer (ETH Zurich)
- G. Kaiser (Columbia Univ. NY)
- I. Crnkovic (Sweden)
- (Univ. of Copenhagen)
- R. Marinescu (Univ. Timisoara)
- SaaS (Stanford)

COURSE CONTENT [TENTATIVE]

1. Introduction. OOP Concepts. SOLID

2. Class design principles (GRASP). Package Design principles

3 – 5. Architectural Patterns

6. Live coding session

7. Midterm?

8 - 9. Enterprise applications patterns

10-12. Design Patterns

13. Quality Attributes

14. Exam review

OBJECTIVES

After completing this course, you should be able to:

- **Identify** the most relevant functional and non-functional **requirements** of a software system and document them
- Generate **architectural alternatives** for a problem by applying major software architectural styles and design patterns
- Analyze and select among them, based on well-known design principles and best practices

VALUE OF SOFTWARE?

Behavior

“a program that works perfect now but is impossible to change”

- Urgent
- Not (always) important

Architecture

“a program that doesn’t work perfect now but can be easily changed”

- Not (particularly) urgent
- Important

WHAT IS (GOOD) ARCHITECTURE?

Supports:

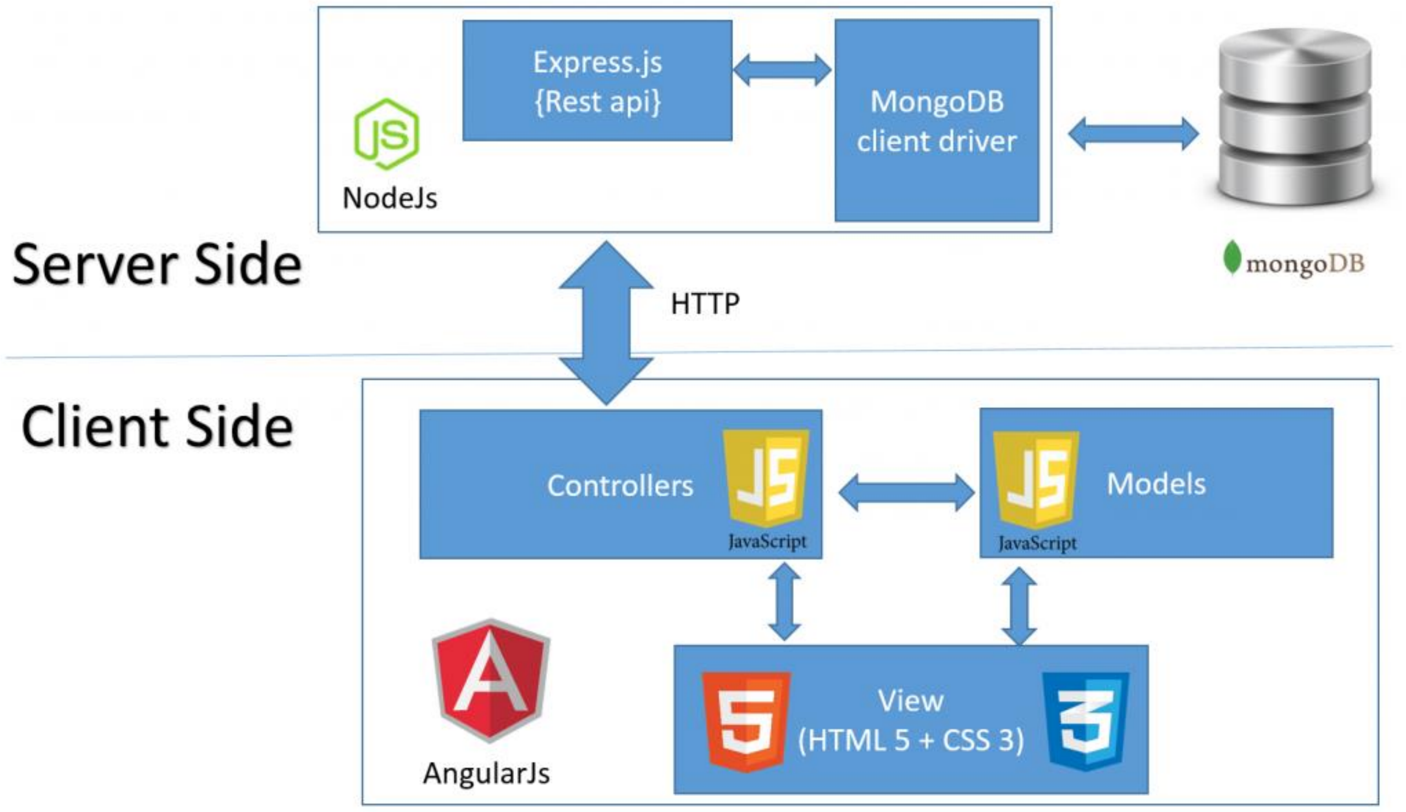
- The use cases and operation of the system ("screaming" architecture).
- The maintenance of the system.
- The development of the system.
- The deployment of the system.

By:

- Setting boundaries (decoupling)
- Leaving options open (separate policies from details)

WHAT IS ARCHITECTURE NOT?

Technology stack



https://relevant.software/blog/how-to-choose-a-technology-stack-for-your-web-application/

DECOUPLING LEVELS

Source

- components all execute in the same address space,
- communicate with each other using simple function calls.
- a single executable loaded into computer memory

Deployment

- independent deployable units (ex. jar files, DLLs, shared libraries)

Service

- dependencies at the level of data structures,
- communication solely through network packets
- every execution unit is entirely independent of source and binary changes to others

SOFTWARE DESIGN TECHNIQUES

What are Software Design Techniques?

- A **set of practices** for analysing, decomposing, and modularising software system architectures

- Characterized by structuring the system architecture on the basis of its *components* rather than the *actions* it performs.

LEARNING SD TECHNIQUES

Junior Developer (knows rules)

- knows algorithms, data structures and programming languages
- writes programs, although not always good ones

Senior Developer (understands principles)

- understands software design & programming paradigms with pros and cons
- importance of cohesion, coupling, information hiding, dependency management etc.

Technical Architect (applies patterns (i.e. proven solutions))

- develops design models
- understands how design solutions interact and can be integrated

WHAT DO YOU NEED?

Knowledge

- attending lectures AND reading books – terminology, concepts, principles, methods, and theories

Understanding

- using your knowledge by applying it in hands-on activities, e.g., practical exercises, assignments, projects, discussions

Skills

- actively and continuously work hard, gaining experience (practice!)

TODAY'S OUTLINE

Basic OOP Review

SOLID Class Design Principles

REFERENCES

[1] Martin, Robert C., *Clean Architecture: A Craftsman's Guide to Software Structure and Design*. Boston, MA: Prentice Hall, 2017.

[2] http://butunclebob.com/ArticleS.UncleBob.PrinciplesOfOod

[3] SOLID ebook

[4] https://martinfowler.com/articles/injection.html

WHAT IS A CLASS?

A type that encapsulates

- State (Attributes)
- Constructors
- Behavior (Methods)

Class candidates:

- Person 🙂
- Mihaela 🚫
- AddAccount 🚫

HOW TO DECLARE A CLASS (JAVA)

```
class ClassName [extends ParentName implements
InterfaceName(s)]

{

      [modifier(s)] type attribute1;

                  …

      [modifier(s)] return_type method1(param_list)

      {//method body here}

}
```

Access modifiers: public, protected, private

“Mutability” modifier: final

“Scope” modifier: static

THE PERSON CLASS

```
class Person {
      private int birthYear;
      private String firstName, lastName;
      private boolean employed;
      private int nrOfLegs;

      //constructor(s)
      //setters & getters
}
```

What should we make static?

What should we make final?

THE PERSON CLASS

```
//code here
class Person {
        private final int birthYear;
        private String firstName, lastName;
        private boolean employed;
        private static int nrOfLegs;

        //constructor(s)
        //setters & getters
..
}
```

~~static~~

final

OVERLOADING METHODS

Define in a class, methods with the same name and different:

- Number of parameters
- Type of parameters
- Return type

```
class Person {

  public int calculateAge() {

    return Date.currentYear() -
birthYear;}

  public int calculateAge (int year )
{

    return year - birthYear;}

  public float calculateAge() {

    return Date.currentYear() -
birthYear;}}
```

WHAT IS AN OBJECT?

A specific entity of the type defined by the class.

⇒ Has specific values for the attributes

me is an object of type Person.

```
Person me = new Person();
me.firstName = “Mihaela”
me.lastName = “Dinsoreanu”
me.employed = true
me.numberOfLegs = ??
```

HOW TO USE OBJECTS?

Call public methods to **query the object** (getters)

```
String name = me.getfirstName() + "  " +
me.getlastName();

int birthY = me.getbirthYear();

int age = me.calculateAge();

…
```

HOW TO USE OBJECTS? (2)

Call public methods to **set attribute values** (setters)

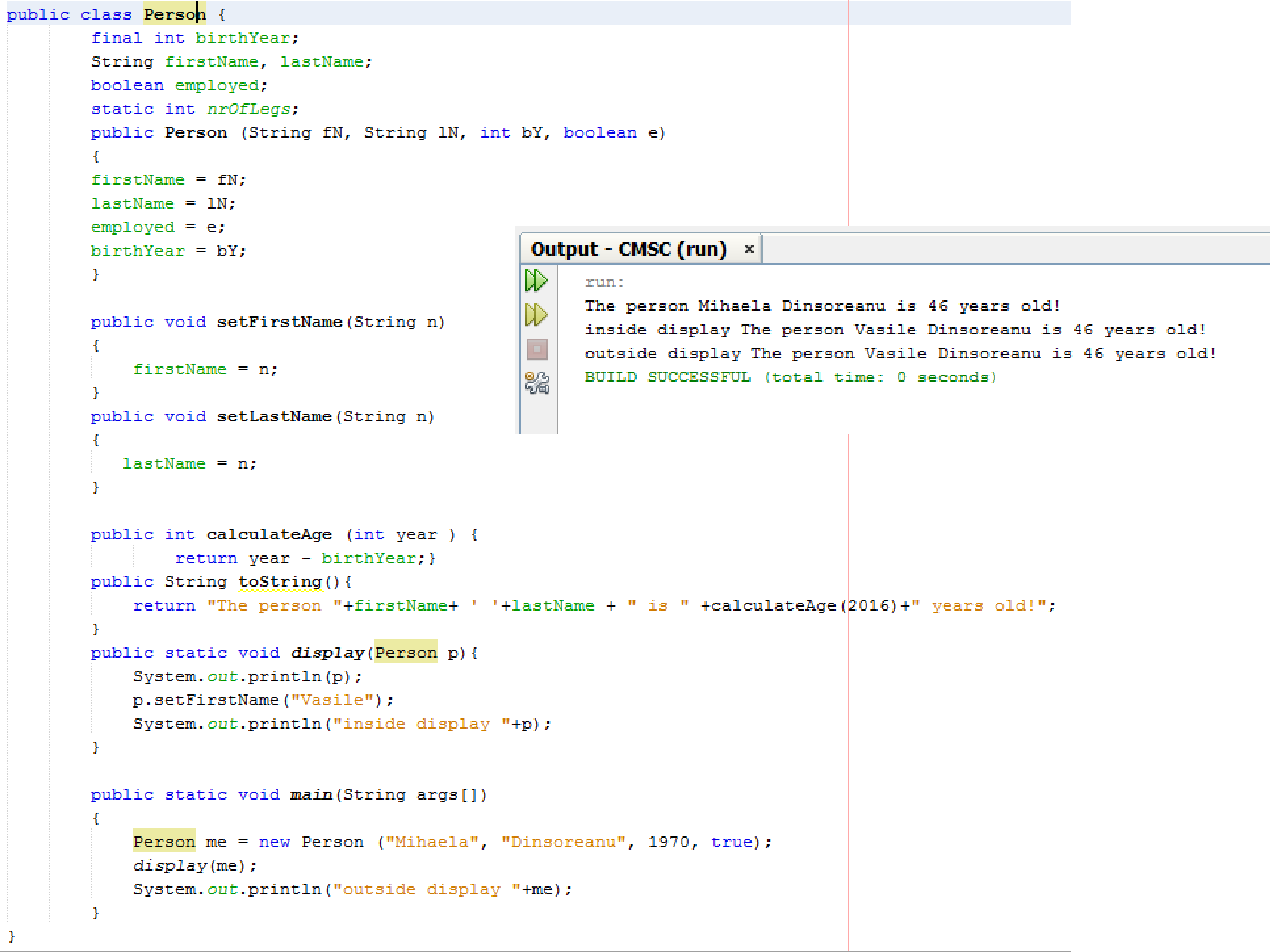
```
me.setfirstName(fN);
me.setlastName(lN);
me.setBirthYear(bY);
me.setAge(int age);
```

…

How are parameters passed?

- By value !

- Primitive type?
- Reference?



```java
public class Person {
        final int birthYear;
        String firstName, lastName;
        boolean employed;
        static int nrOfLegs;
        public Person (String fN, String lN, int bY, boolean e)
        {
        firstName = fN;
        lastName = lN;
        employed = e;
        birthYear = bY;
        }

        public void setFirstName(String n)
        {
            firstName = n;
        }
        public void setLastName(String n)
        {
           lastName = n;
        }

        public int calculateAge (int year ) {
                return year - birthYear;}
        public String toString(){
            return "The person "+firstName+ ' '+lastName + " is " +calculateAge(2016)+" years old!";
        }
        public static void display(Person p){
            System.out.println(p);
            p.setFirstName("Vasile");
            System.out.println("inside display "+p);
        }

        public static void main(String args[])
        {
            Person me = new Person ("Mihaela", "Dinsoreanu", 1970, true);
            display(me);
            System.out.println("outside display "+me);
        }
}
```

Output - CMSC (run) ×

```
run:
The person Mihaela Dinsoreanu is 46 years old!
inside display The person Vasile Dinsoreanu is 46 years old!
outside display The person Vasile Dinsoreanu is 46 years old!
BUILD SUCCESSFUL (total time: 0 seconds)
```

WHAT IS INHERITANCE?

The way to reuse CLASSES to create more specific classes

Represents the IS-A relationship

The attributes and methods of the superclass are inherited in the subclass

FINAL classes cannot be subclassed!

Examples:

- Student IS-A Person
- Dog IS-A Animal
- Truck IS-A Vehicle
- Square IS-A Rectangle 🚫

OVERRIDING METHODS

Change the inherited code of the method

The method signature DOESN'T change!

Can all methods be overridden?

- FINAL methods cannot!

```
class Student extends Person {
…
 public String toString() {
 return "This is student "+ firstName + " " +
lastName;}
}
```

WHAT IS COMPOSITION?

The way to reuse OBJECTS in order to create more complex objects.

Represents HAS-A relationship

Examples:

- House HAS-A Door
- Vehicle HAS-A Engine
- Person HAS-A Heart

```
class Person {
        private Heart heart;
        private String firstName, lastName;
             …
        Person (Heart h, String fN, …)
}

class Heart {
        private double pulse;
        private double weight;
            ..
}
```

INHERITING A SUPERCLASS

What is inherited?

- Attributes
- Methods
- Constructors

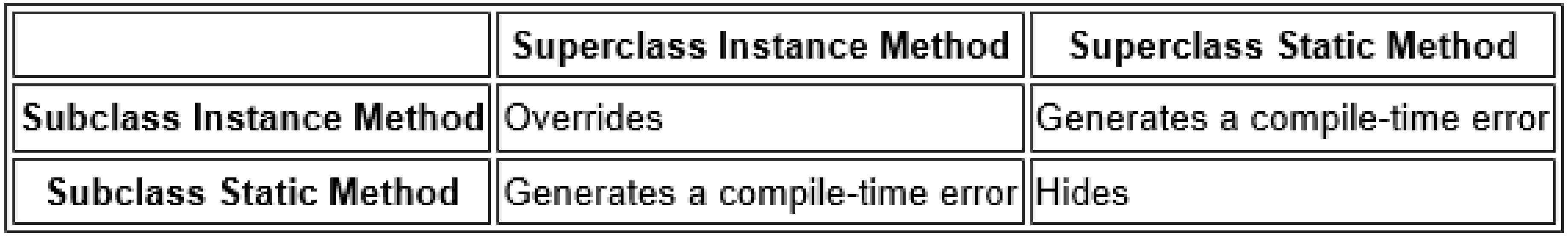
What can you do in a subclass?

- use the inherited fields and methods directly
- declare a field in the subclass with the same name as the one in the superclass, thus *hiding* it (not recommended).
- declare new fields in the subclass that are not in the superclass.
- write a new *instance* method in the subclass that has the same signature as the one in the superclass, thus *overriding* it. (NOT FINAL!!!)

INHERITING A SUPERCLASS [2]

- write a new *static* method in the subclass that has the same signature as the one in the superclass, thus *hiding* it.
- declare new methods in the subclass that are not in the superclass.
- write a subclass constructor that invokes the constructor of the superclass, either implicitly or by using the keyword super.

Defining a Method with the Same Signature as a Superclass's Method



	Superclass Instance Method	Superclass Static Method
Subclass Instance Method	Overrides	Generates a compile-time error
Subclass Static Method	Generates a compile-time error	Hides

```
class Base {
    private int i;
    public int getI() {return i;}
    public void setI(int j) {i = j;}
}

public class Test extends Base {
    public static void main(String args[]) {
        Test t = new Test();
        t.setI(5);
        System.out.println(i);
        System.out.println(t.getI());
} }
```

POLYMORPHISM

The possibility to consider an instance as having different types. NOT ANY TYPE!!!!

```
String display(Person p) {
      System.out.println(p);
}
Person me, you;
me = new Person();
you = new Student();
```

`display(me);` => "me@32342323"

`display(you);` => "This is student ….."

CLASS DESIGN PRINCIPLES

Single Responsibility

Open-Closed

Liskov Substitution

Interface Segregation

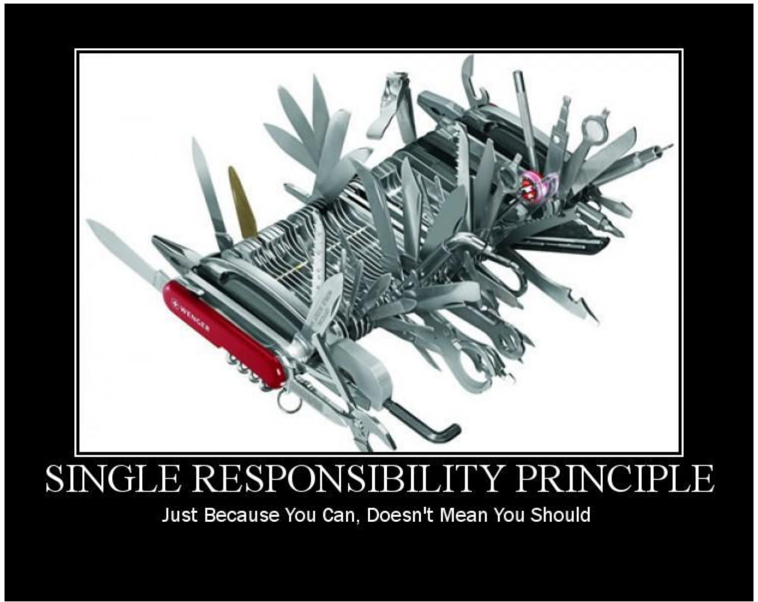
Dependency Inversion

SINGLE RESPONSIBILITY

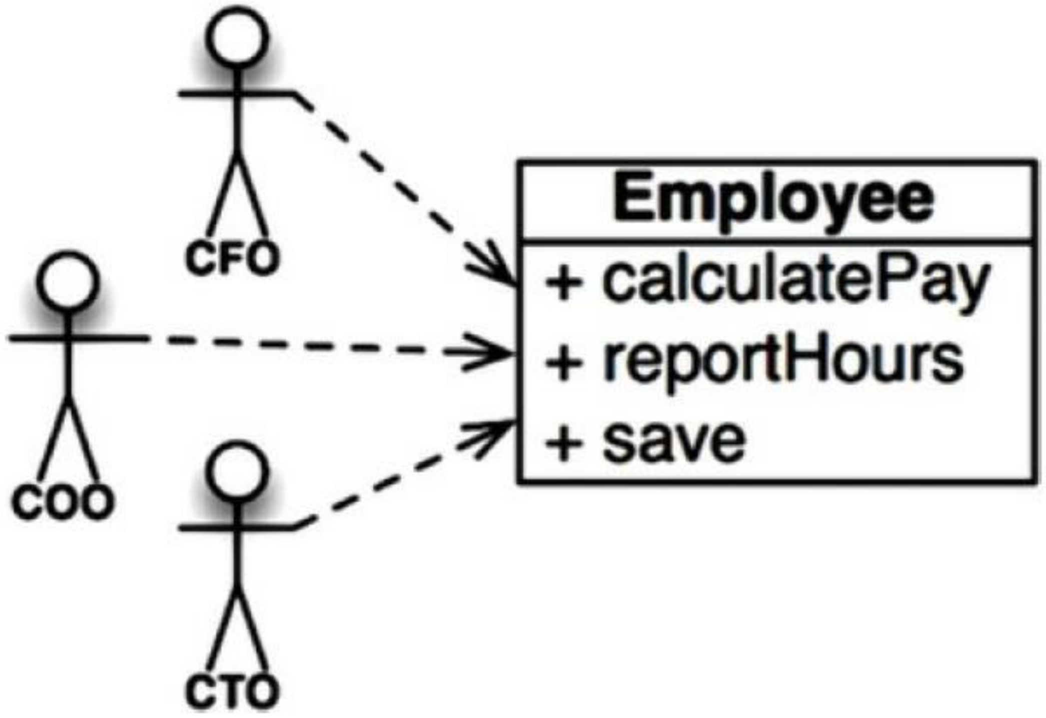
A module should have one, and only one, **reason to change.**

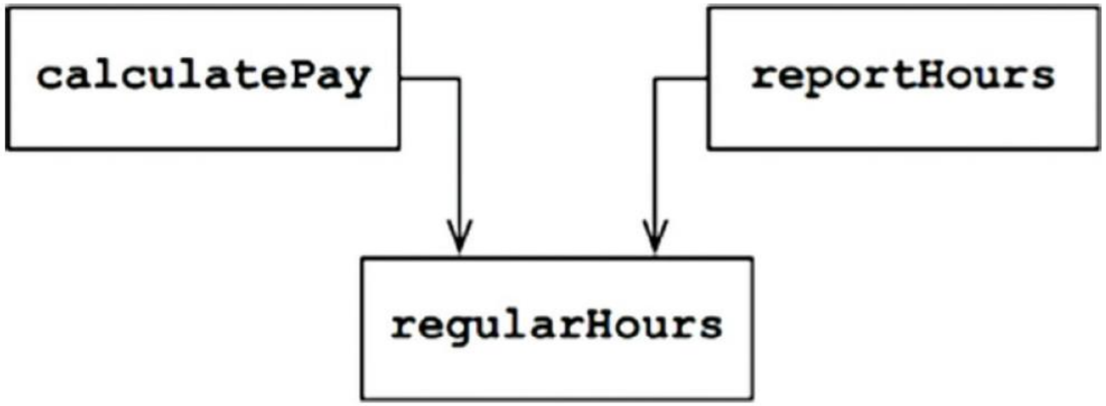
A module should be **responsible to one,** and only one, **user or stakeholder.**

A module should be **responsible to one,** and only one, **actor.**

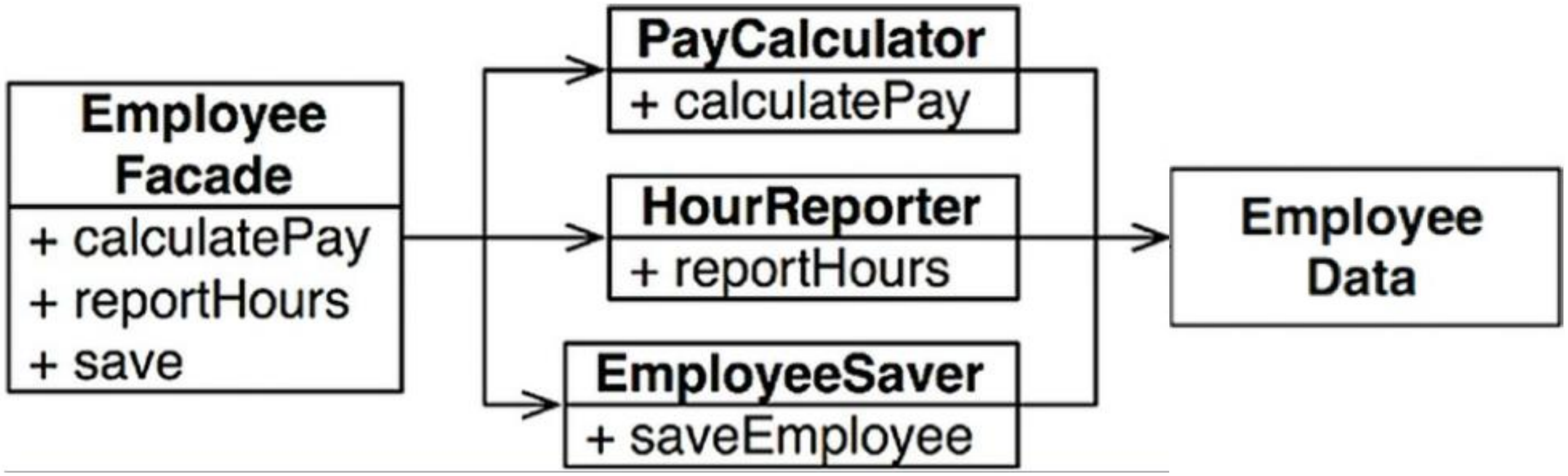

SINGLE RESPONSIBILITY PRINCIPLE
Just Because You Can, Doesn't Mean You Should

EXAMPLE

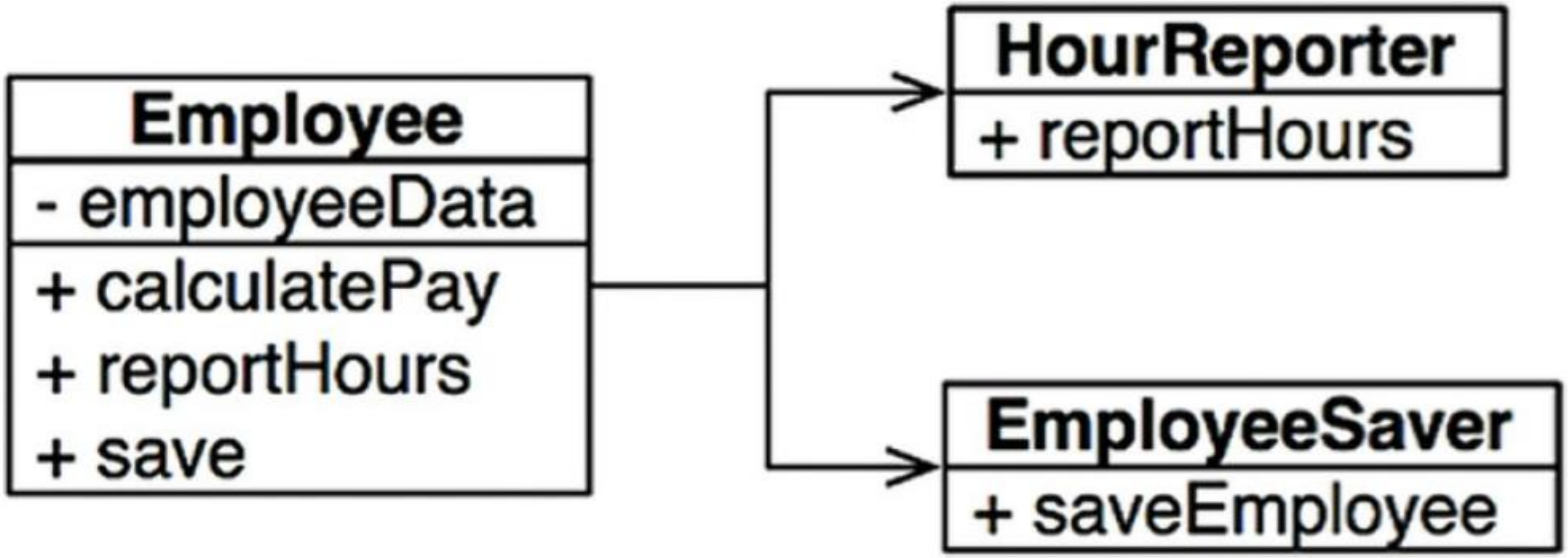

CFO
COO
CTO
Employee
+ calculatePay
+ reportHours
+ save


calculatePay
reportHours
regularHours

SOLUTION(S)


Employee Facade
+ calculatePay
+ reportHours
+ save
PayCalculator
+ calculatePay
HourReporter
+ reportHours
EmployeeSaver
+ saveEmployee
Employee Data

OR...


Employee
- employeeData
+ calculatePay
+ reportHours
+ save
HourReporter
+ reportHours
EmployeeSaver
+ saveEmployee

OPEN-CLOSED PRINCIPLE (OCP)

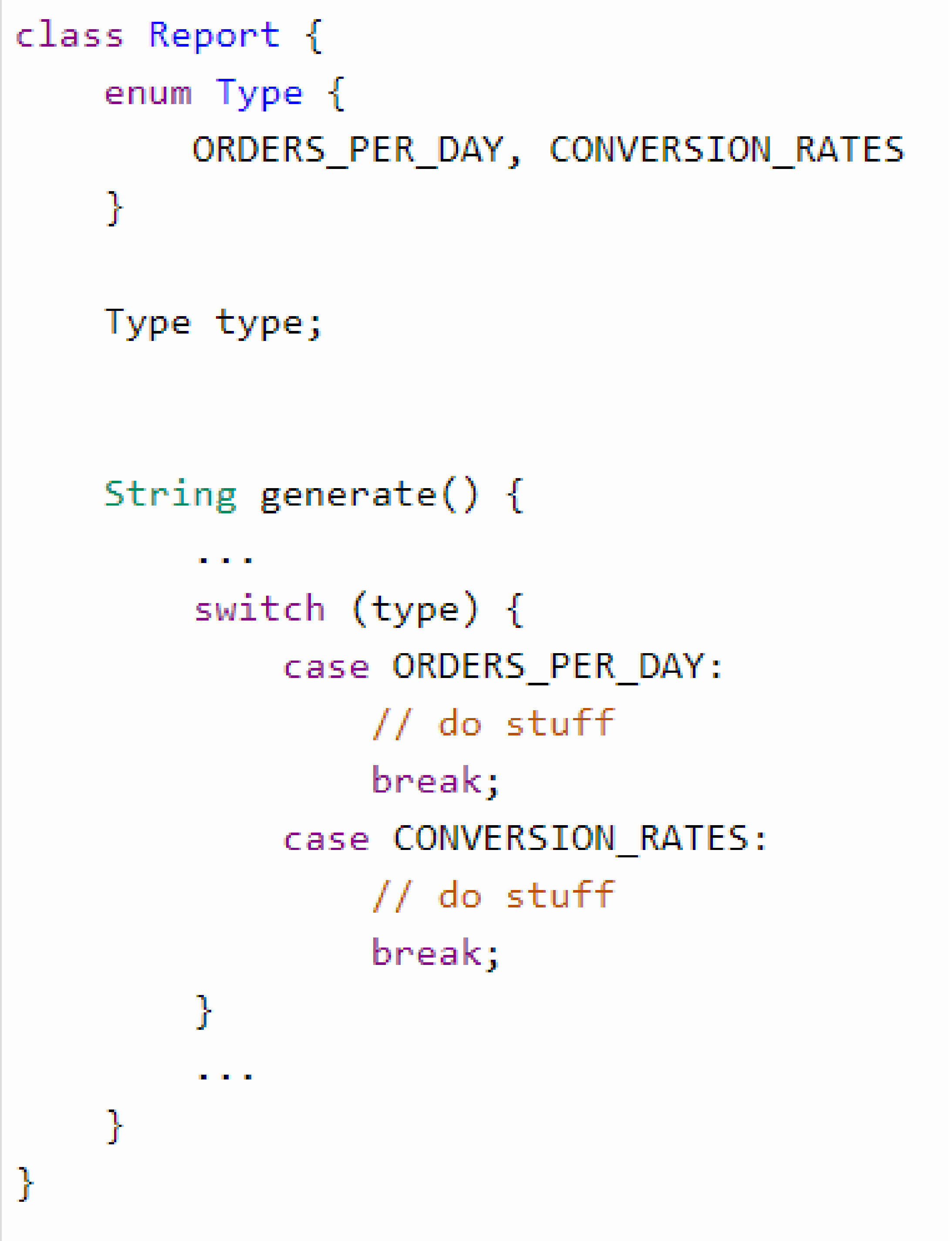
A software artifact should be open for extension but closed for modification.

EXTENSION??

- by inheritance?
- by composition?

EXAMPLE

What if a new type of report is needed?



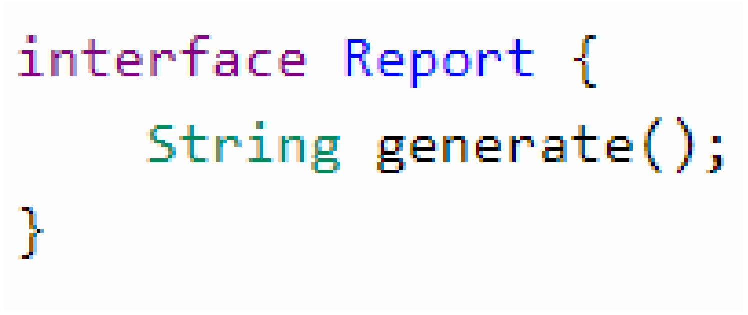
```
class Report {
    enum Type {
        ORDERS_PER_DAY, CONVERSION_RATES
    }

    Type type;


    String generate() {
        ...
        switch (type) {
            case ORDERS_PER_DAY:
                // do stuff
                break;
            case CONVERSION_RATES:
                // do stuff
                break;
        }
        ...
    }
}
```

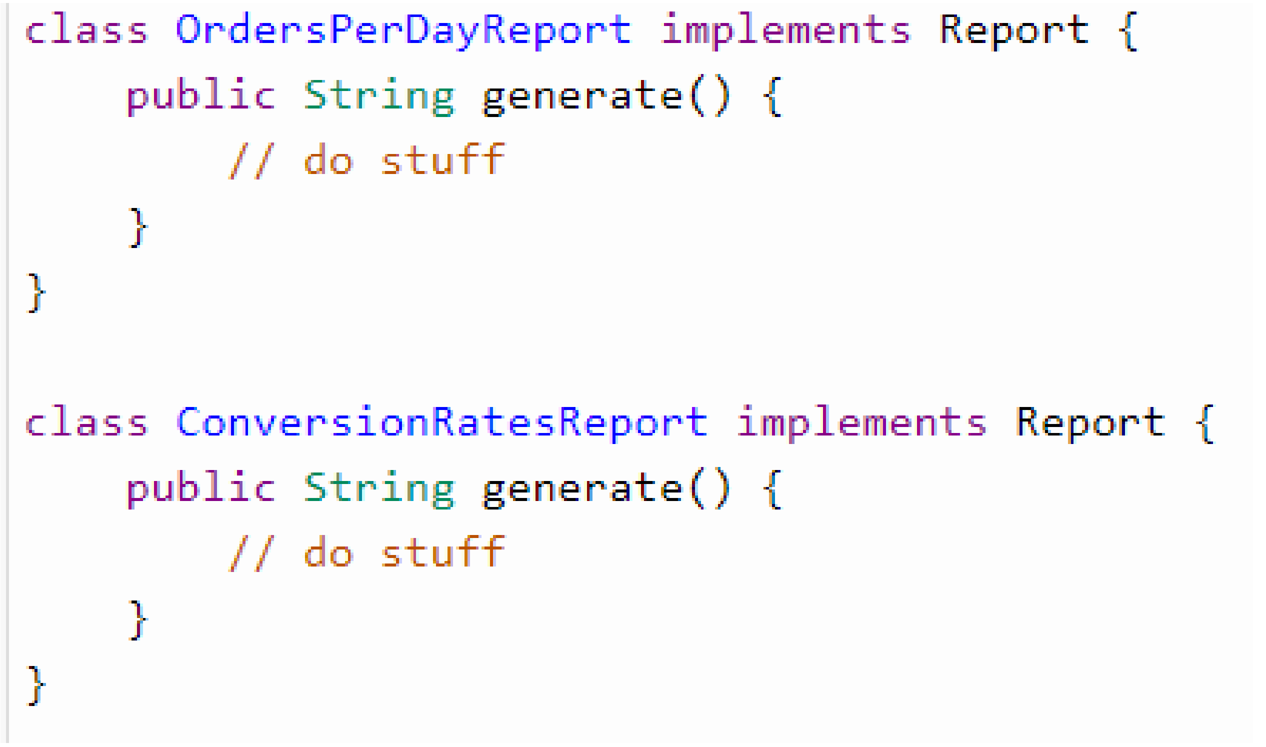
SOLUTION

Generate abstraction



```
interface Report {
    String generate();
}
```

Implement the abstraction



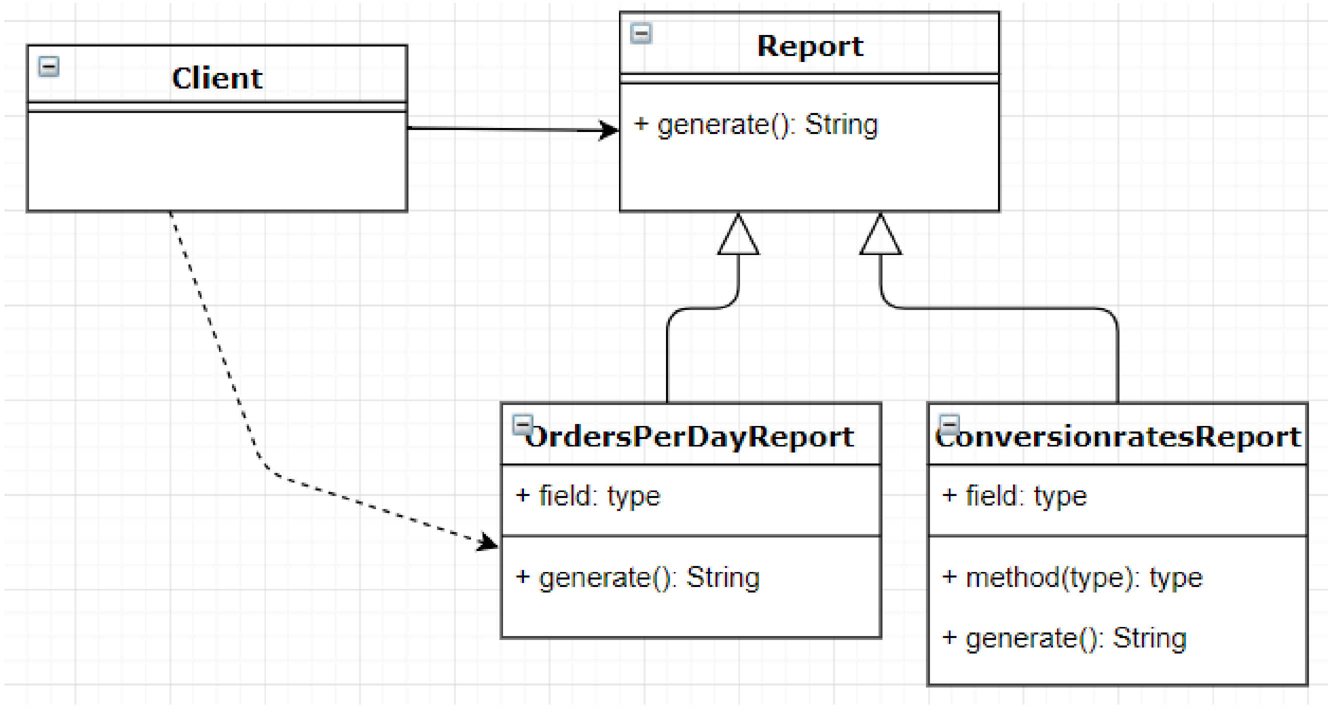
```
class OrdersPerDayReport implements Report {
    public String generate() {
        // do stuff
    }
}

class ConversionRatesReport implements Report {
    public String generate() {
        // do stuff
    }
}
```

TECHNIQUE

Dynamic polymorphism

Dependency management



Static polymorphism

- Templates, generics

WHAT IF…

… another column has to be added into the report?

… the report format should be different if displayed in a web interface or printed?

… the same report should be more/less detailed depending on the user?

⇒The challenge is to decide what to close!

⇒Strategic closure

STRATEGIC CLOSURE

Use abstraction to gain explicit closure

- provide class methods which can be dynamically invoked to determine *general* policy decisions
- design using abstract ancestor classes

Use "Data-Driven" approach to achieve closure

- place volatile policy decisions in a separate location (e.g. a configuration file or a separate object)
- minimizes future change locations

LISKOV SUBSTITUTION PRINCIPLE (LSP)

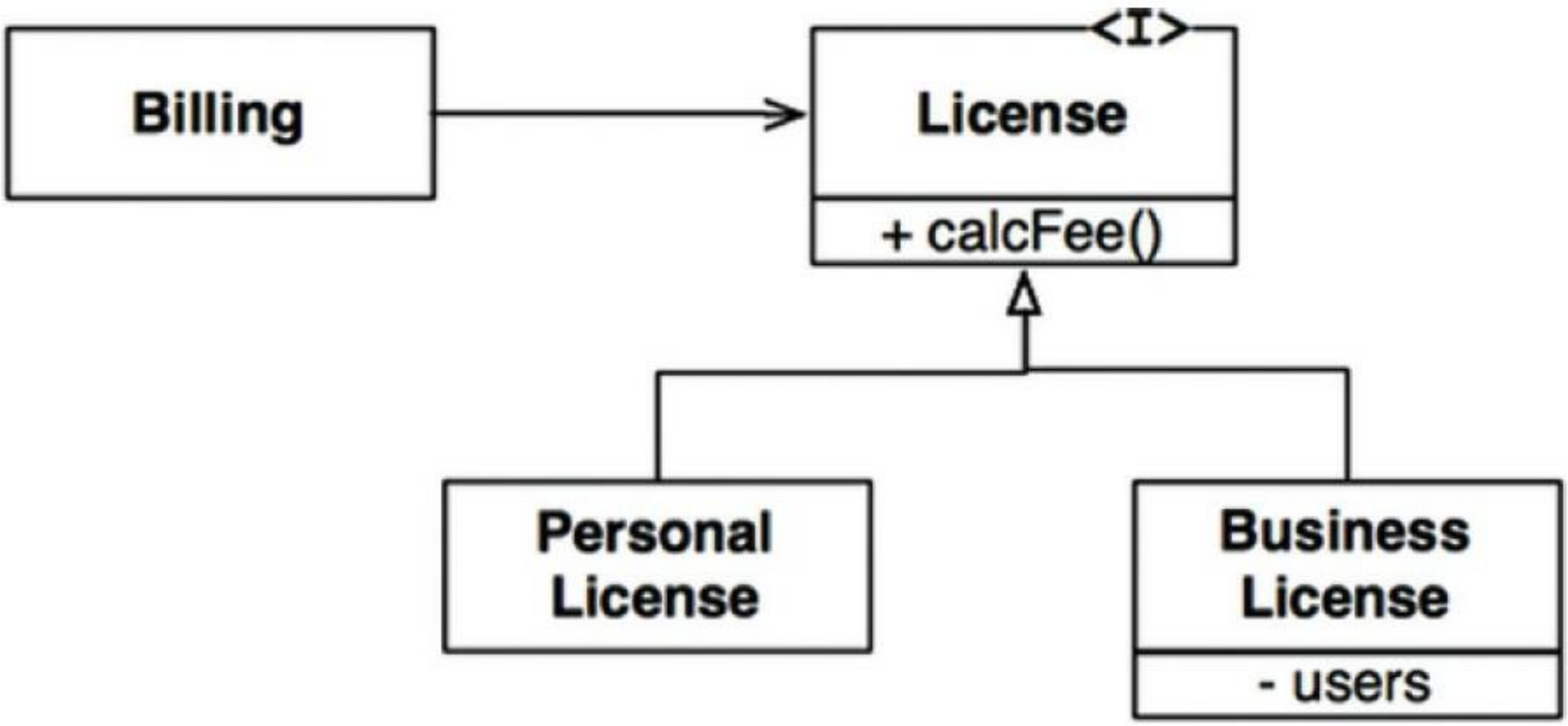
"What is wanted here is something like the following substitution property:

If for each object o1 of type S there is an object o2 of type T such that for all programs P defined in terms of T, the behavior of P is unchanged when o1 is substituted for o2 then S is a subtype of T."

[Barbara Liskov, 1988]

LISKOV SUBSTITUTION PRINCIPLE
If It Looks Like A Duck, Quacks Like A Duck, But Needs Batteries - You Probably Have The Wrong Abstraction

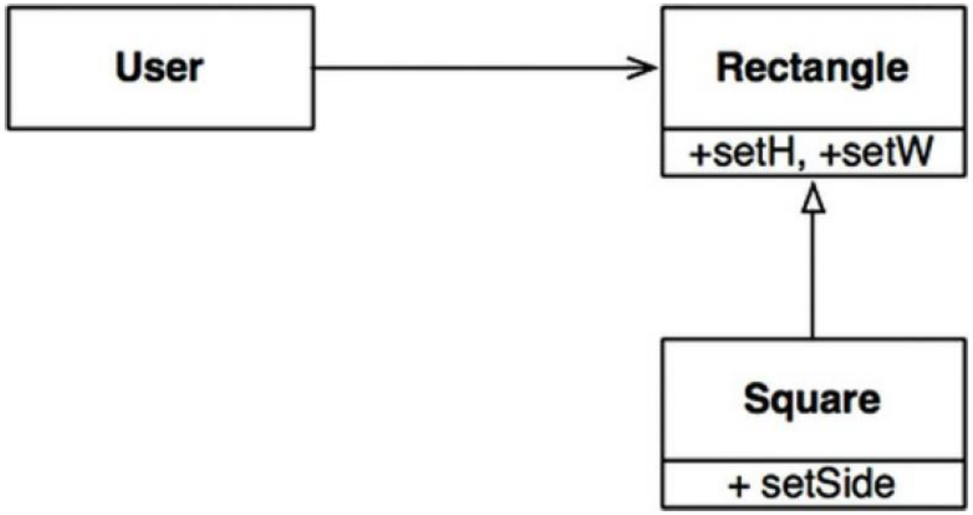
EXAMPLE


Billing
<I>
License
+ calcFee()
Personal License
Business License
- users

LSP VIOLATION

```
class Rectangle
{
     private:
      double width;
      double height;
     public:
      void setW(double w)…
      void setH (double h)…
}
```

class Square inherits Rectangle ?



IS-A RELATIONSHIP REFERS TO BEHAVIOR

Override setW () and setH ()

=> Duplicated code

Problem! Static binding (C++)

```
void g(Rectangle& r)
{
 r.setW(4);
 r.setH(5);
}
```

PROBLEM CONTINUED

Dynamic binding (Java)

```
class Rectangle
{
     private double width;
     private double height;

     public void setW (double w)…
     public void setH (double h)…
}

void g(Rectangle r)
{
      r.setW(4);
      r.setH(5);
      assert(r.getW()*r.getH()== 20);
}
```

DESIGN BY CONTRACT [BERTRAND MEYER]

Basic notation: (*P*, Q: assertions, i.e. properties of the state of the computation. *A*: instructions).

$\{P\}\ A\ \{Q\}$

Total correctness: Any execution of *A* started in a state satisfying *P* will terminate in a state satisfying Q.

Design by contract

1. **Preconditions P** of the derived class method **are no stronger** than the base class method.
2. **Postconditions Q** of the derived class method **are no weaker** than the base class method.

LSP HEURISTICS

It is illegal for a derived class, to override a base-class method with a NOP method

NOP = a method that does nothing

Solution 1: Inverse Inheritance Relation

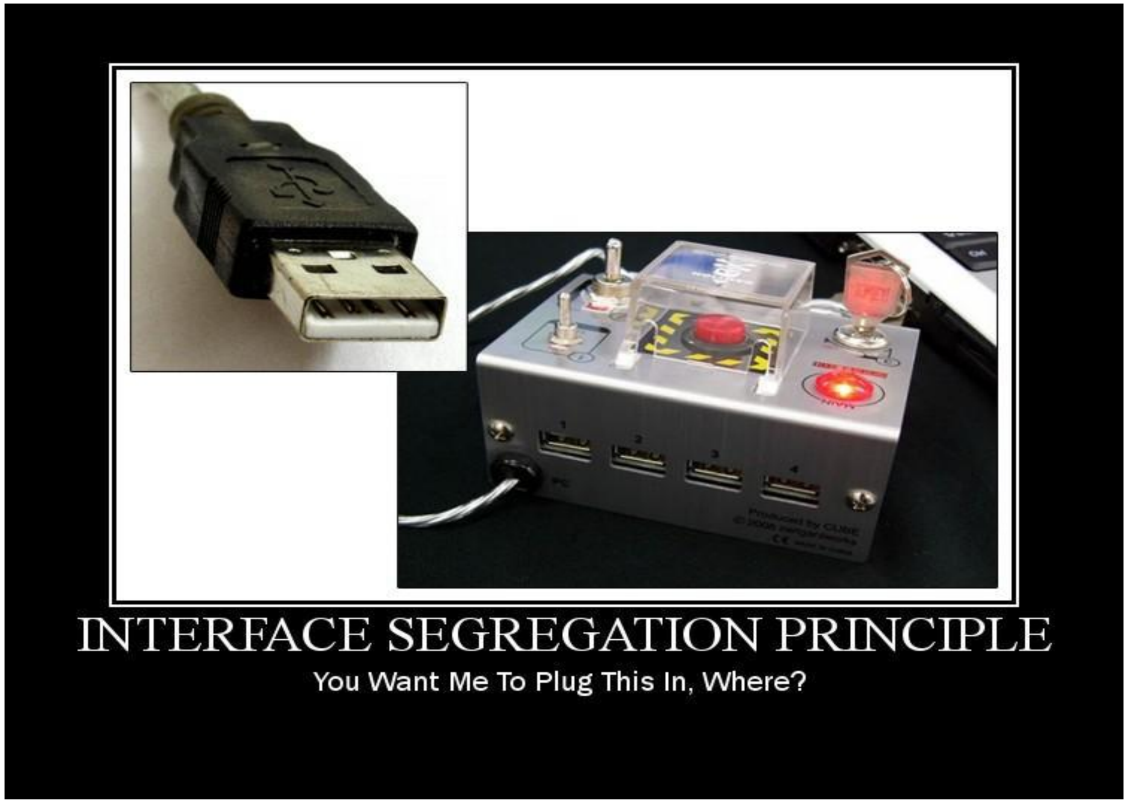
- if the initial base-class has only additional behavior

Solution 2: Extract Common Base-Class

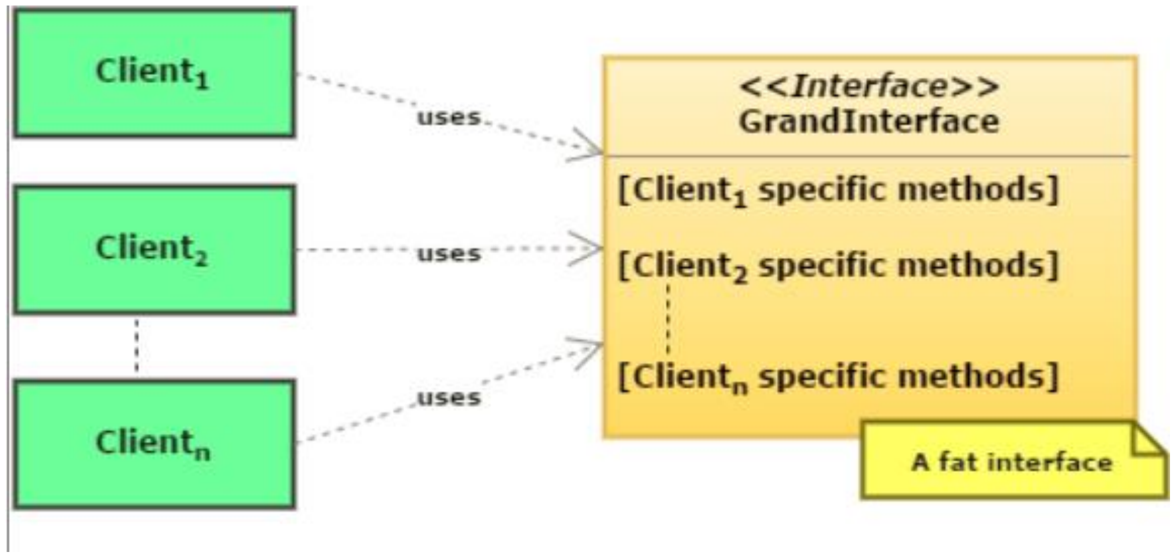
- if both initial and derived classes have different behaviors

INTERFACE SEGREGATION PRINCIPLE (ISP)

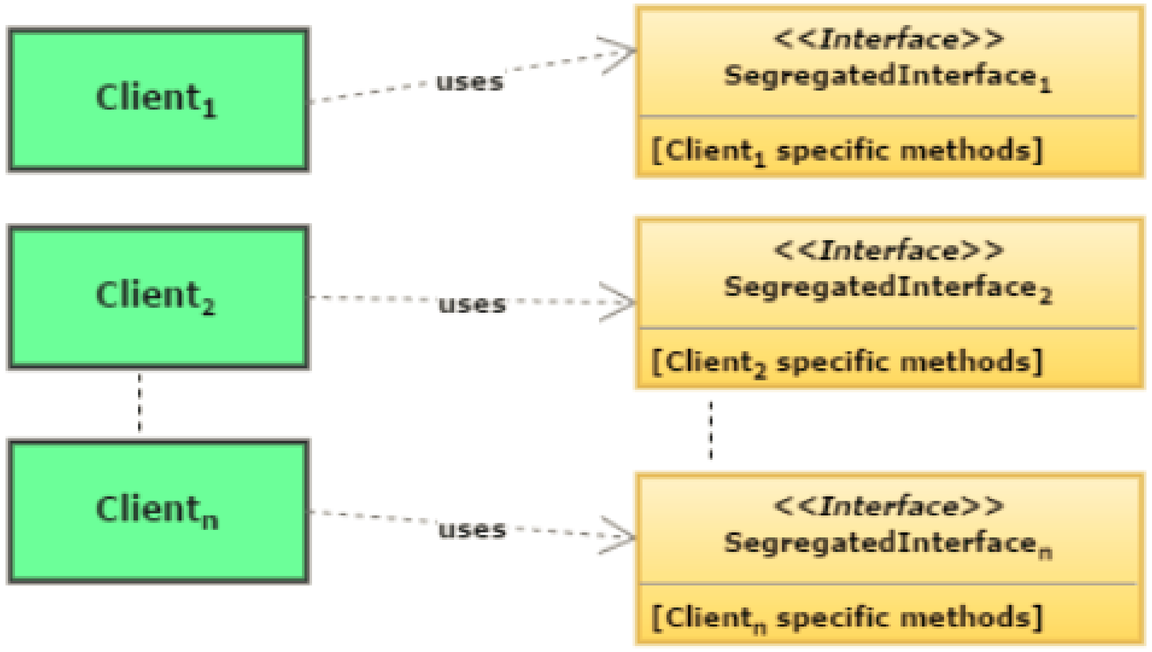
Clients should not be forced to depend upon interfaces that they don't use.


INTERFACE SEGREGATION PRINCIPLE
You Want Me To Plug This In, Where?

ISP

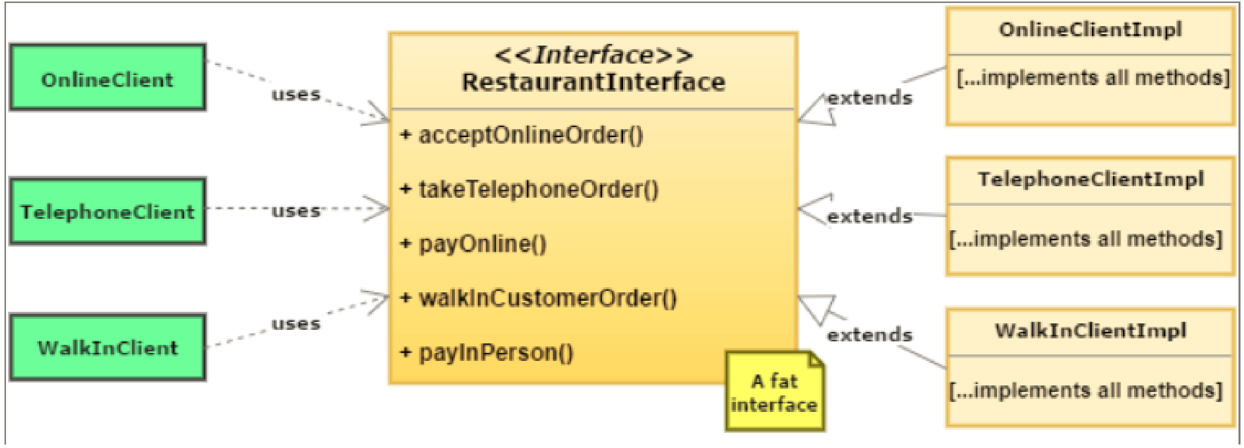


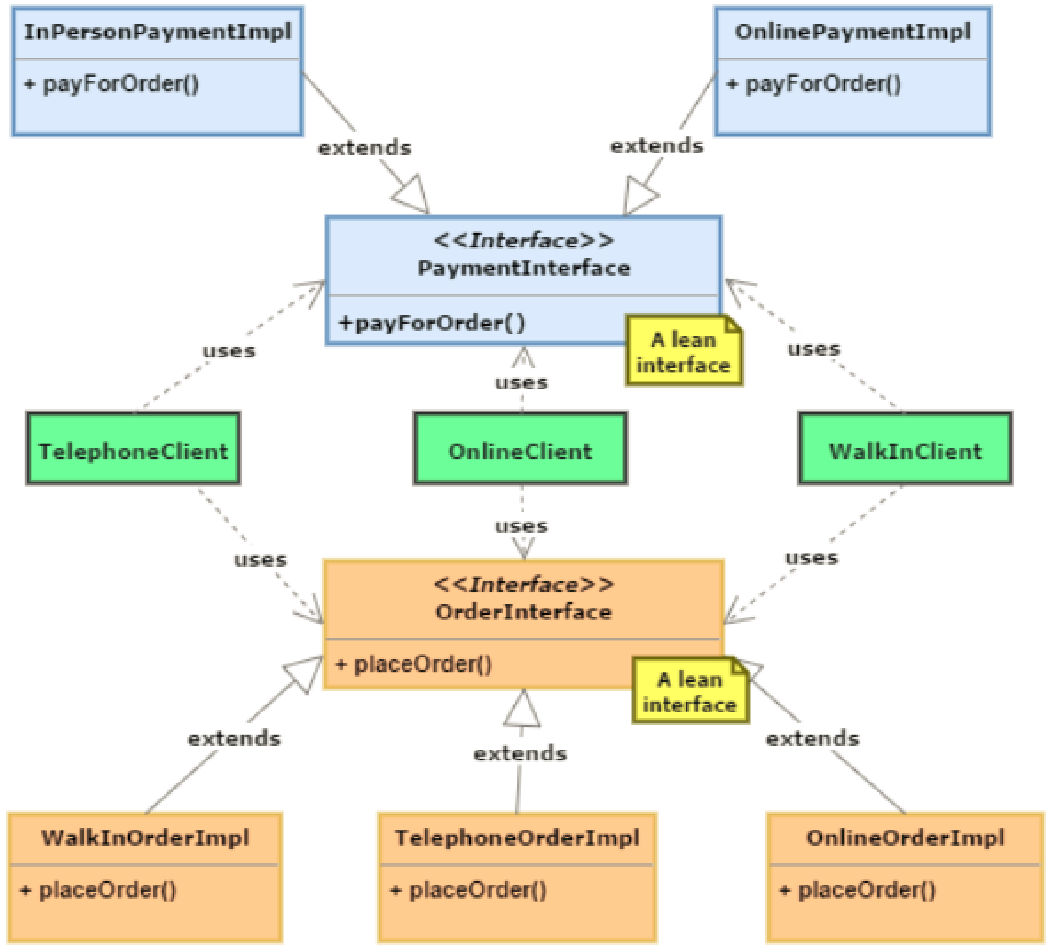
Client$_1$
Client$_2$
Client$_n$
uses
uses
uses
<<Interface>>
GrandInterface
[Client$_1$ specific methods]
[Client$_2$ specific methods]
[Client$_n$ specific methods]
A fat interface



https://www.javabrahman.com/programming-principles/interface-segregation-principle-explained-examples-java

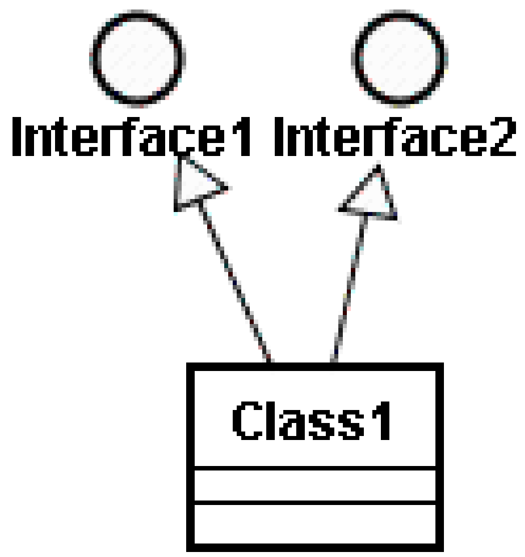
ISP EXAMPLE

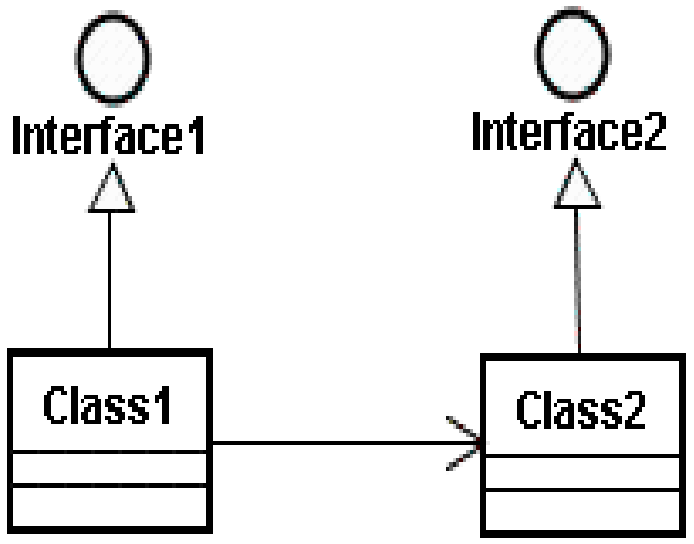

OnlineClient
TelephoneClient
WalkInClient
uses
uses
uses
<<Interface>>
RestaurantInterface
+ acceptOnlineOrder()
+ takeTelephoneOrder()
+ payOnline()
+ walkInCustomerOrder()
+ payInPerson()
A fat interface
extends
extends
extends
OnlineClientImpl
[...implements all methods]
TelephoneClientImpl
[...implements all methods]
WalkInClientImpl
[...implements all methods]


InPersonPaymentImpl
+ payForOrder()
OnlinePaymentImpl
+ payForOrder()
extends
extends
<<Interface>>
PaymentInterface
+payForOrder()
A lean interface
uses
uses
uses
TelephoneClient
OnlineClient
WalkInClient
uses
uses
uses
<<Interface>>
OrderInterface
+ placeOrder()
A lean interface
extends
extends
extends
WalkInOrderImpl
+ placeOrder()
TelephoneOrderImpl
+ placeOrder()
OnlineOrderImpl
+ placeOrder()

ISP EXAMPLE

Separation thru Multiple Inheritance vs. separation thru delegation



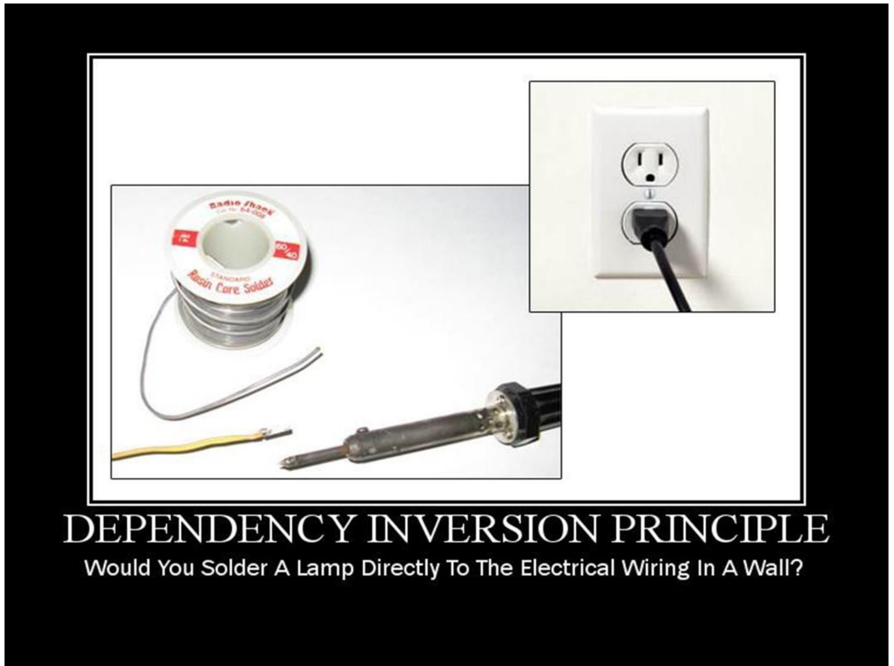


DEPENDENCY INVERSION PRINCIPLE (DIP)

I.High-level modules should ***not*** depend on low-level modules.

Both should depend on abstractions.

II.Abstractions should **not** depend on details. Details should depend on abstractions.


DEPENDENCY INVERSION PRINCIPLE
Would You Solder A Lamp Directly To The Electrical Wiring In A Wall?

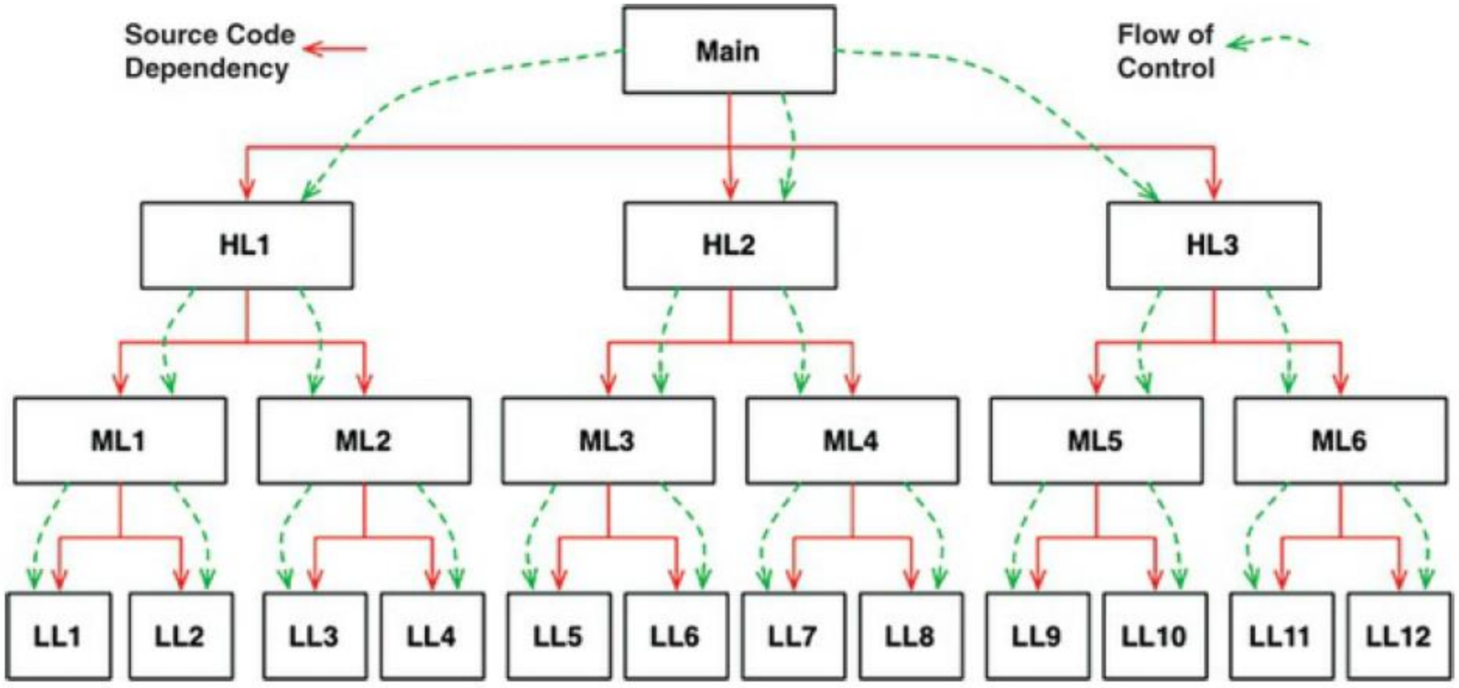
DEPENDENCY INVERSION MOTIVATION

Traditional calling tree Main

#include (C++)

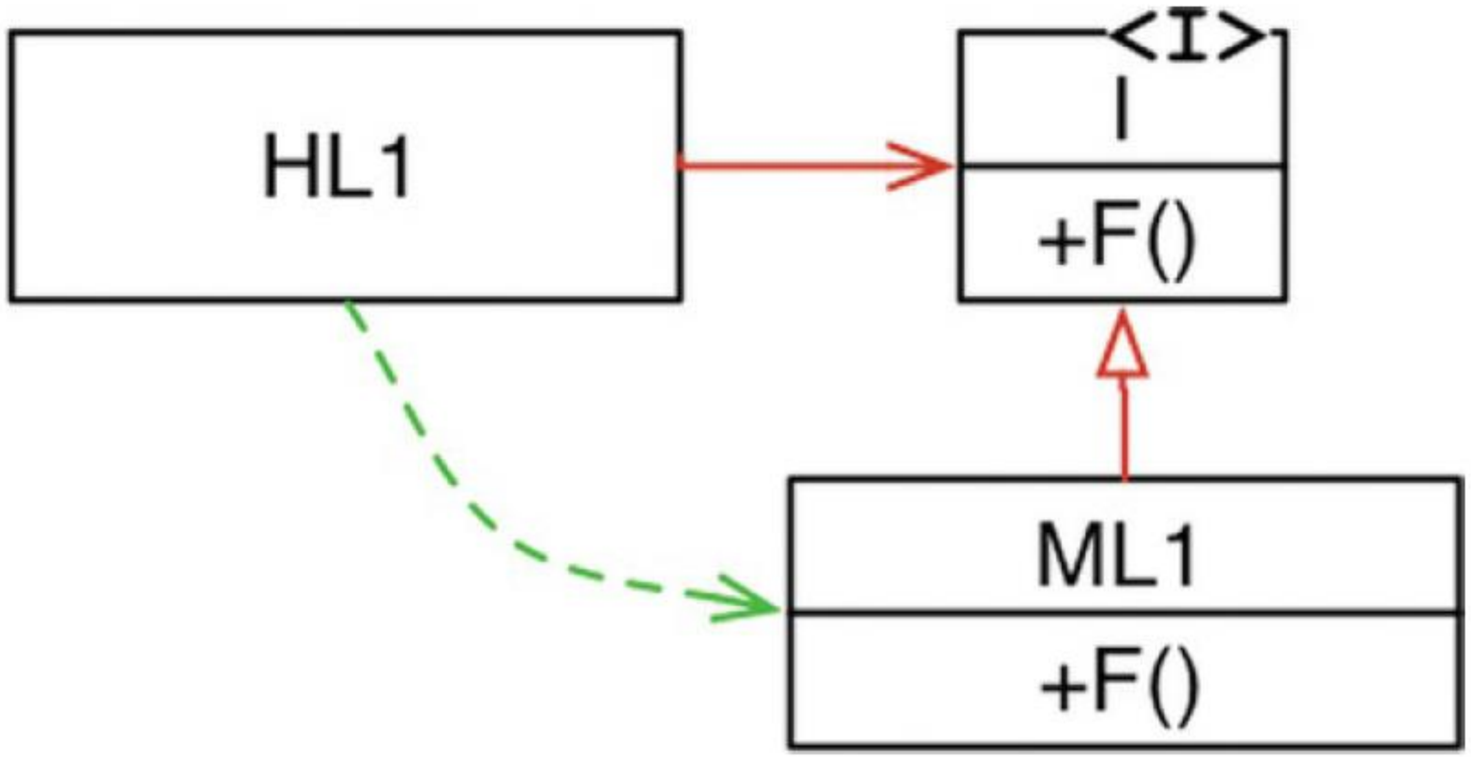
import (Java)

using (C#)

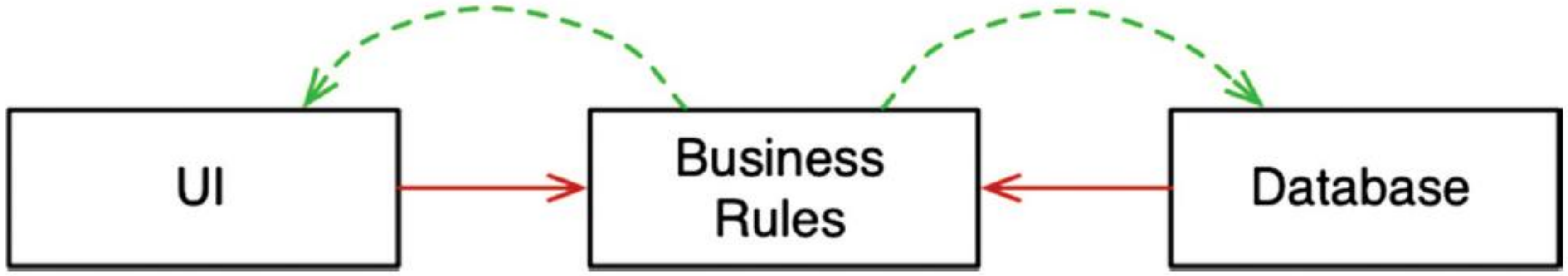


DEPENDENCY INVERSION

The power of polymorphism!



DEPENDENCY INVERSION IN LAYERS

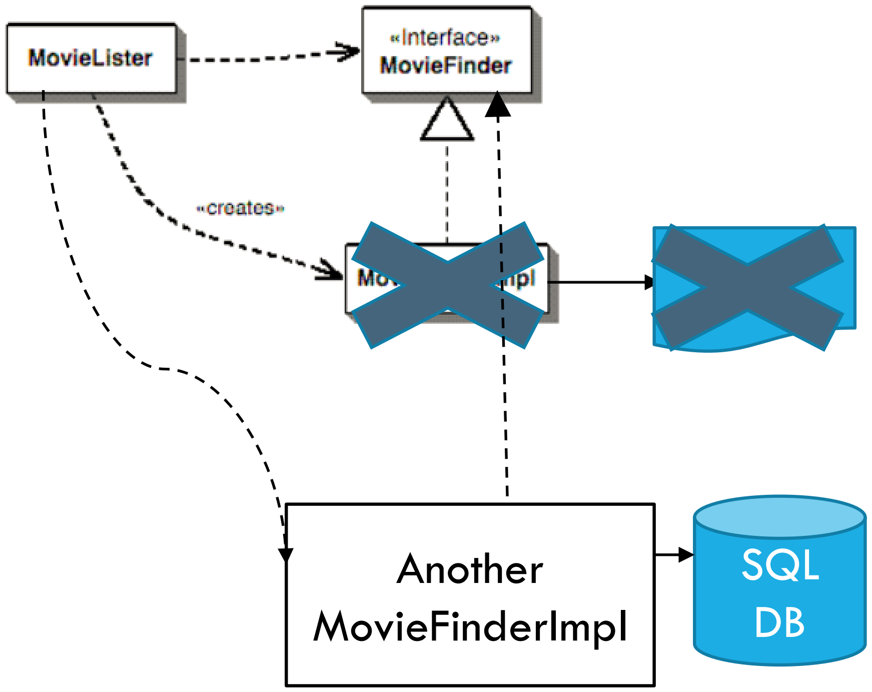


- The business rules, the UI, and the database can be compiled into three separate components or deployment units (e.g., jar files, DLLs, etc.)
- The component containing the business rules will not depend on the components containing the UI and database => The business rules can be *deployed independently* of the UI and the database.
- Changes to the UI or the database need not have any effect on the business rules.
- If the modules in your system can be deployed independently, then they can be *developed independently* by different teams.

DEPENDENCY INJECTION

```
public class MovieLister {
  private MovieFinder finder;

  public MovieLister() {
    this.finder = new
MovieFinderImpl("movies.txt")
}…}
```



https://martinfowler.com/articles/injection.html

TYPES OF DEPENDENCY INJECTION

Constructor

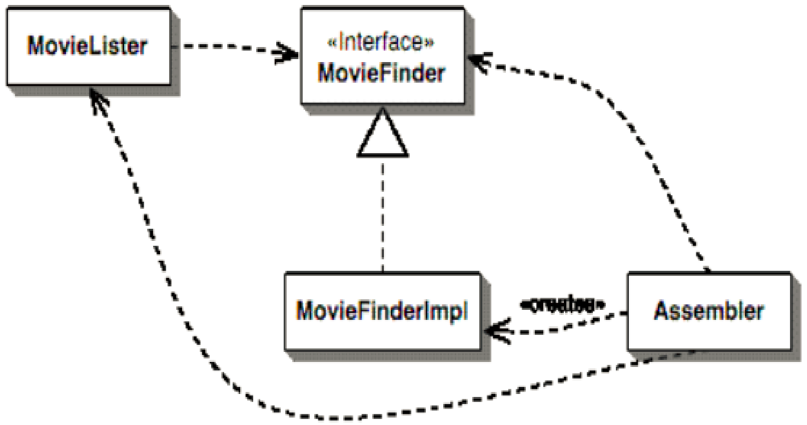
```
public MovieLister(MovieFinder finder) {
     this.finder = finder; }

class TextMovieFinder implements MovieFinder
   public TextMovieFinder(String filename) {
        this.filename = filename; }

//configuration code in a different class
private MutablePicoContainer
configureContainer() {
    MutablePicoContainer pico = new
DefaultPicoContainer();
    Parameter[] finderParams =  {new
ConstantParameter("movies.txt")};

pico.registerComponentImplementation(MovieFind
er.class, TextMovieFinder.class,
finderParams);

pico.registerComponentImplementation(MovieList
er.class);
    return pico;
}
```



```
//test the code

MutablePicoContainer pico =
configureContainer();

MovieLister lister =
(MovieLister)
pico.getComponentInstance(MovieLi
ster.class);
```

SETTER DI WITH SPRING

```
 public class MovieLister {
   private MovieFinder finder;
   public void setFinder(MovieFinder finder) {
         this.finder = finder; }}

 class TextMovieFinder...
 …
   public void setFilename(String filename) {
       this.filename = filename;
   }

 //test
 public void testWithSpring() throws Exception
{
   ApplicationContext ctx = new
FileSystemXmlApplicationContext("spring.xml");
   MovieLister lister = (MovieLister)
ctx.getBean("MovieLister");
 }
```

```
//configuration
<beans>
    <bean id="MovieLister"
class="spring.MovieLister">
        <property
name="finder">
            <ref
local="MovieFinder"/>
        </property>
    </bean>
    <bean id="MovieFinder“
class="spring.TextMovieFinder">
        <property
name="filename">

<value>movies1.txt</value>
        </property>
    </bean>
</beans>
```

WRAP-UP

Our objective is to develop GOOD software architectures

EACH PROBLEM HAS SEVERAL SOLUTIONS!

- Design
- Technology
- Code
- Deployment

Basic Design Principles have to be considered!