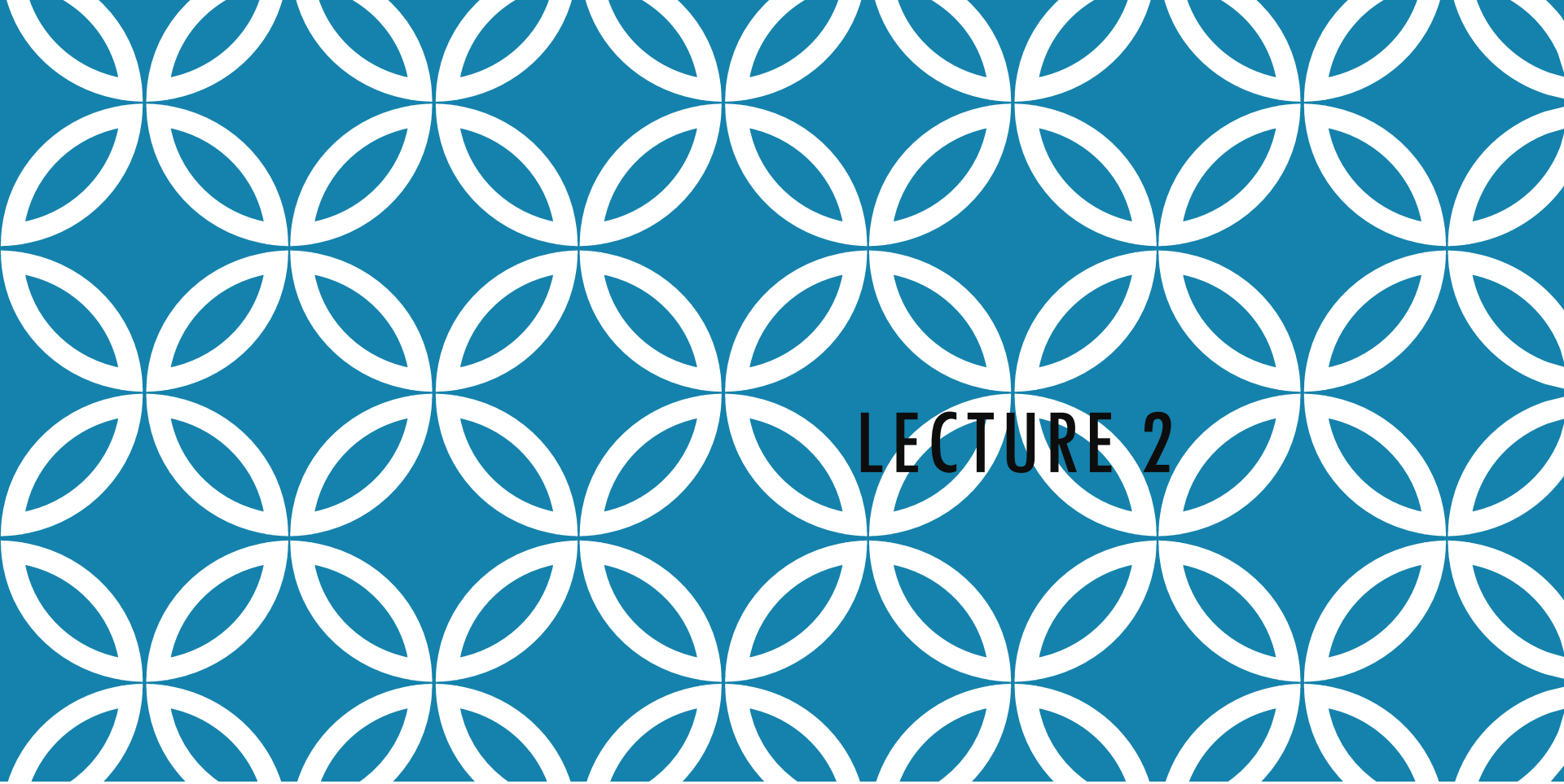


LECTURE 2

Design principles

CONTENT

General Responsibility ASsignment Principles (GRASP)

Package Design

- Cohesion Principles
- Coupling Principles

REFERENCES

- Robert Martin
  http://butunclebob.com/ArticleS.UncleBob.PrinciplesOfOod

- Taylor, R., Medvidovic, N., Dashofy, E., Software Architecture: Foundations, Theory, and Practice, 2010, Wiley

- Craig Larman, Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design and Iterative Development, 3rd Ed, Addison Wesley, 2004 – Chapters 17, 18.

Courses
- B. Meyer (ETH Zurich)
- R. Marinescu (Univ. Timisoara)

LAST TIME

OOP concepts +

Single Responsibility

Open-Closed

Liskov Substitution

Interface Segregation

Dependency Inversion

CHALLENGE

Overloading and polymorphism

Compiler error?

Output?

```
class Base{
    @Override
    public String toString() { return "This is base";}

}

class Sub extends Base{
    @Override
    public String toString() { return "This is subclass";}
}

class Host{
    public String print(Base b)
    {
        return b.toString() + " din metoda cu base";
    }
   public String print(Sub b)
    {
        return b.toString() + " din metoda cu sub";
    }
 }

public class Polytest {
    public static void main(String[] args){
        Base abase = new Base();
        Sub asub = new Sub();
        Host h = new Host();
        System.out.println(h.print(abase));
        System.out.println(h.print(asub));
    }
}
```

```
Output - CMSC (run)
run:
This is base din metoda cu base
This is subclass din metoda cu sub
```

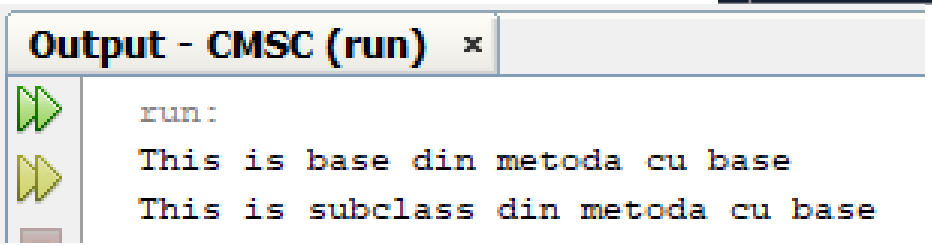
CONTINUED

Delete one method

Error?

Output?

```
class Base{
    @Override
    public String toString() { return "This is base";}

}

class Sub extends Base{
    @Override
    public String toString() { return "This is subclass";}
}

class Host{
    public String print(Base b)
    {
        return b.toString() + " din metoda cu base";
    }
    /*public String print(Sub b)
    {
        return b.toString() + " din metoda cu sub";
    }*/
 }

public class Polytest {
    public static void main(String[] args){
        Base abase = new Base();
        Sub asub = new Sub();
        Host h = new Host();
        System.out.println(h.print(abase));
        System.out.println(h.print(asub));
    }
}
```



HOW TO FAIL WITH SOLID

Single Responsibility Principle: Each class has one (*very small*) specific responsibility. That can lead to thousands of classes.

Open-Closed Principle: Use *inheritance* to add every new feature.

Interface Segregation Principle: Everything is single-inheritance based

Dependency Inversion Principle: Everything is abstracted (data-driven to the extreme).

=> Every single class is ultimately inherited out of the same family tree, sometimes *hundreds* of layers deep.

GRASP

General Responsibility Assignment Software Patterns

OO system = objects sending messages to other objects to complete operations.

Issues:

- **Responsibilities** assigned to objects
- **Interaction** ways between objects

RESPONSIBILITIES

Knowing responsibilities:

- knowing about private encapsulated data;
- knowing about related objects;
- knowing about things it can derive or calculate;

Doing responsibilities:

- doing something itself;
- initiating action in other objects;
- controlling and coordinating activities in other objects;

A responsibility is not the same as a method, but methods are implemented to fulfil responsibilities.

GRASP: GENERAL PRINCIPLES IN ASSIGNING RESPONSIBILITIES

From Craig Larman's 9 principles:

- **Expert**
- **Creator**
- **Controller**
- **Low Coupling**
- **High Cohesion**
- Polymorphism
- Pure Fabrication
- Indirection
- **Don't Talk to Strangers (Law of Demeter)**

CASE STUDY – POS SYSTEM

A Point-Of-Sale (POS) system is an application used (in part) to record sales and handle payments; it is typically used in a retail store.

It includes hardware components such as a computer and bar code scanner, and software to run the system. It interfaces to various service applications, such as a third-party tax calculator and inventory control.

MODELS

Challenge: How do we get from the narrative requirements to an implementable model?

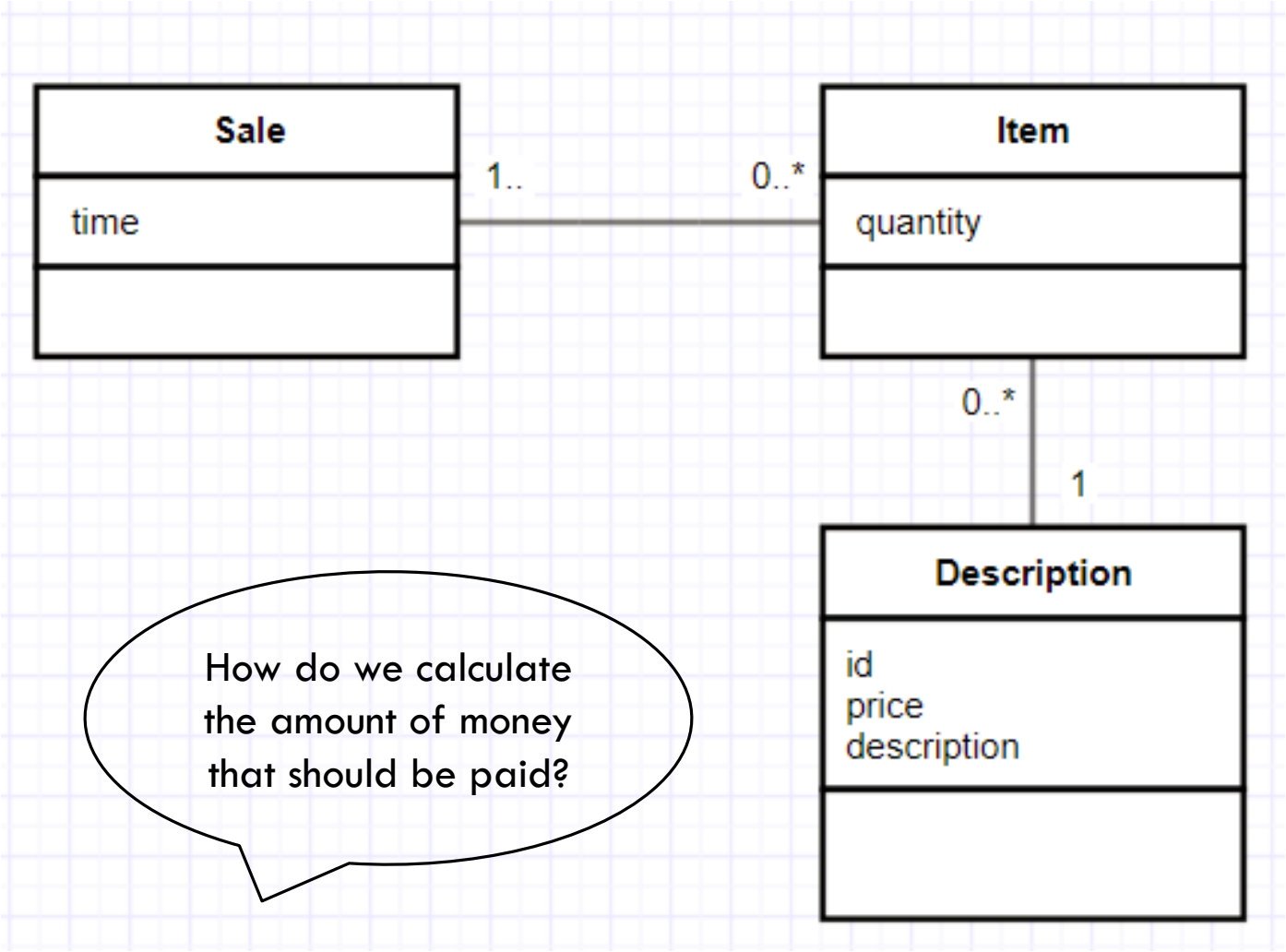
Domain Model

- Sale
- Item
- Payment
- Product
- Register

Design Model

- ?

DESIGN MODEL



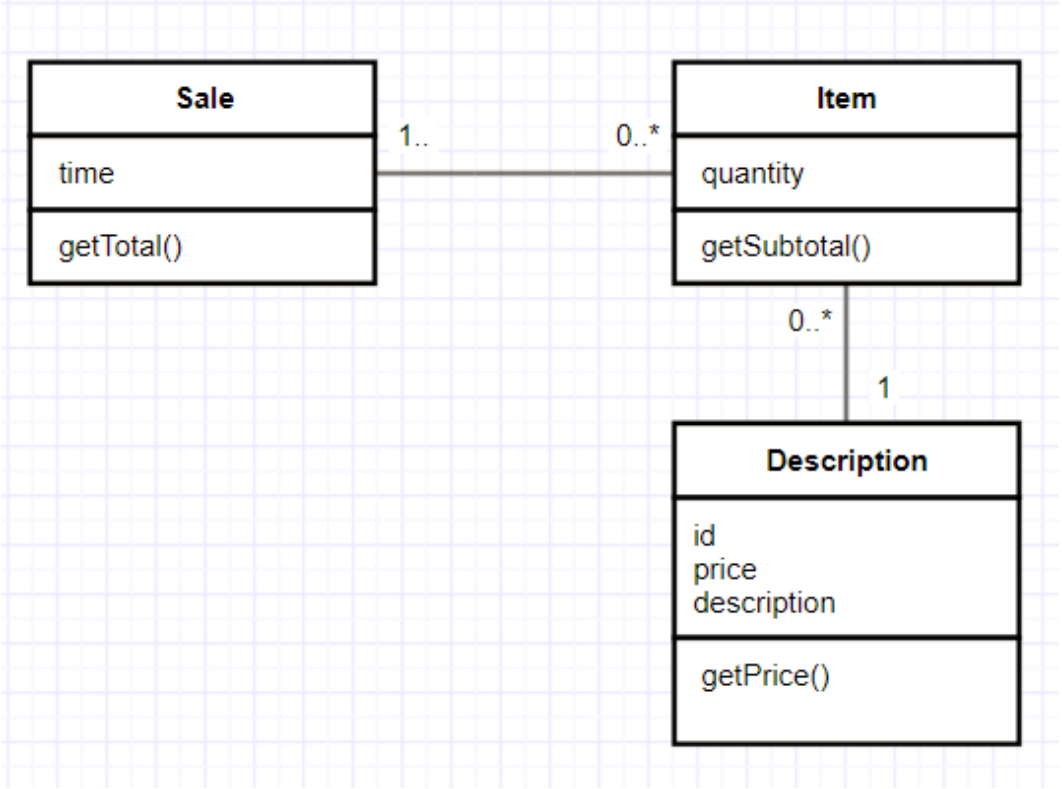
INFORMATION EXPERT

Problem: What is the most basic principle by which responsibilities are assigned in object-oriented design?

Solution: Assign a responsibility to the information expert - the class that **has the necessary information** to fulfil the responsibility.

INFORMATION EXPERT EXAMPLE

In the POS application, what class has the information needed to calculate the total amount of money?



SALE

CONCLUSION

Discussion

- Expert - most used principle in the assignment of responsibilities
- Information is spread across different objects => they need to interact

Benefits

- Information encapsulation is maintained since objects use their own information to fulfill tasks => supports low coupling
- Behavior is distributed across the classes that have the required information => more cohesive "lightweight" class definitions

CREATOR

Problem: Who should be responsible for creating a new instance of some class?

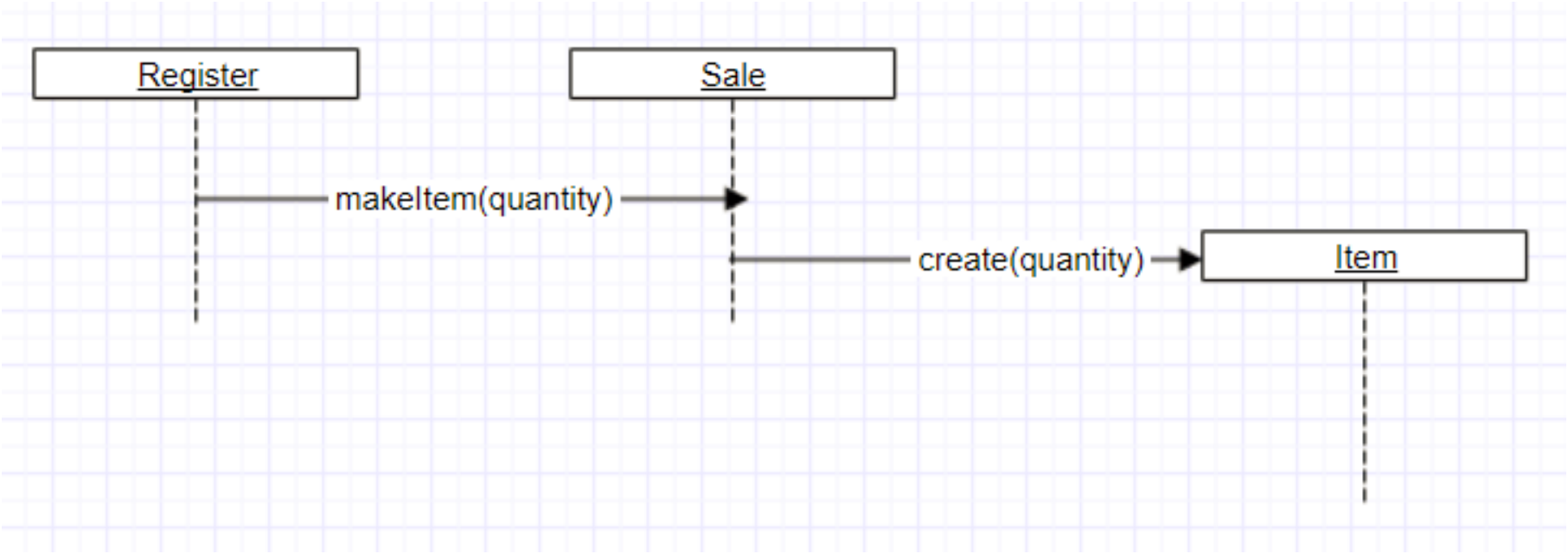
Solution: Assign class B the responsibility to create an instance of class A if one of the following is true:

- B contains A objects
- B closely uses A objects
- B has the initialising data that will be passed to A when it is created.

CREATOR

Example: In the POS application who should be responsible for creating an Item instance?

SALE



CONCLUSION

Discussion:

- Creator guides assigning responsibilities related to the creation of objects.
- Sometimes a creator is the class that has the initialising data that will be used during creation.

For example, who should be responsible to create a Payment instance ?

Benefits:

- Low Coupling is supported

Issues:

- Complex creation procedures
- Solution ?

CONTROLLER

Problem: Who should be responsible for handling a system event?

- A system event is a high level event generated by an external actor.
- A Controller is a non-user interface object responsible for handling a system event.

CONTROLLER

Solution: Assign the responsibility for handling a system event to a class representing one of the following choices:

- Facade controller
  - handles all the events
  - represents the overall "system"
- Role controller
  - handles the events associated to the role
  - represents a person in the real-world
- Use-case controller
  - handles the events associated to a use-case
  - represents an artificial handler

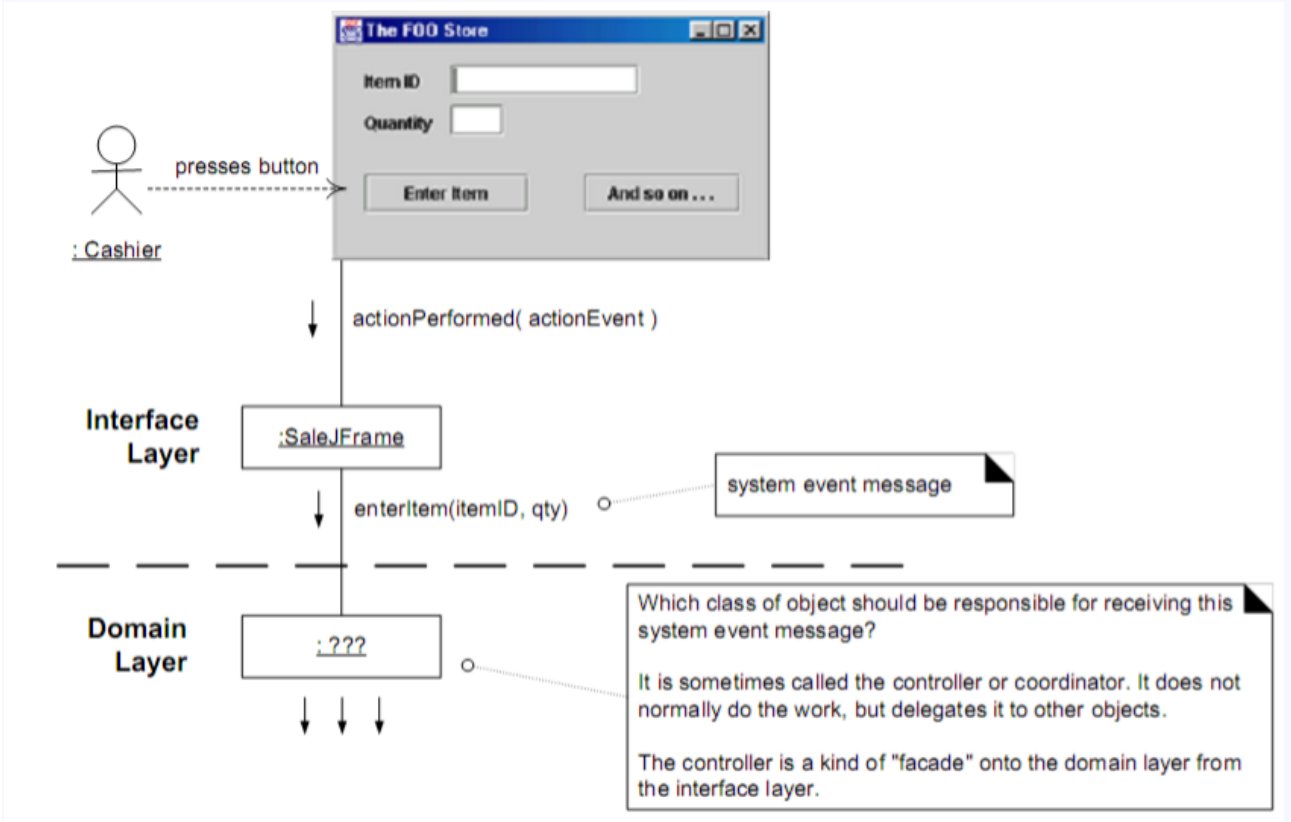
CONTROLLER

Example: In the point of sale application the current system operations have been identified as:

endSale()

enterItem()

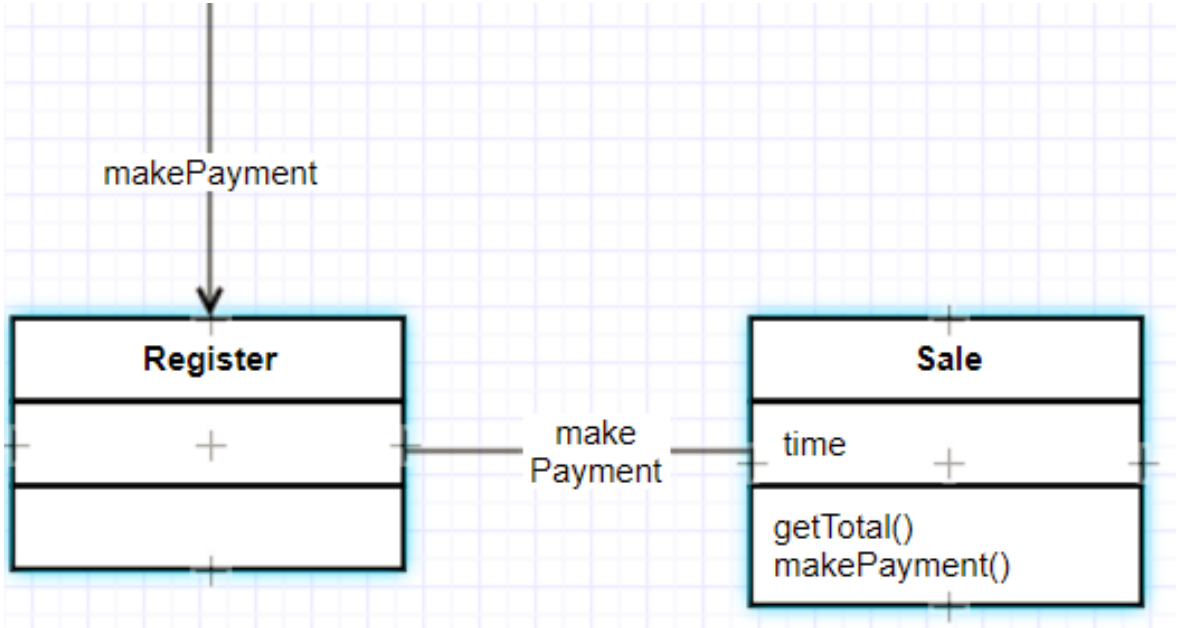
makePayment()



SOLUTION

By the Controller pattern, here are some choices:

- Register, POSSystem: represents the overall "system“ (Façade controller)
- ProcessSaleSession, ProcessSaleHandler: represents a handler of all system events of a use case scenario (Use-case controller)



DISCUSSION

- Usually a controller delegates to other objects the work that needs to be done; it coordinates or controls the activity.
- Facade controllers are suitable when there are not "too many" system events
- A use case controller is an alternative to consider when placing the responsibilities in a facade controller leads to designs with low cohesion or high coupling
- Controller class is called bloated if
  - The class is overloaded with too many responsibilities.
    - Solution – Add more controllers
  - Controller class performs many tasks itself.
    - Solution – controller class has to delegate things to others.

CONCLUSIONS

Benefits:

Increased potential for reusable components:

- it ensures that business or domain processes are handled by the layer of domain objects rather than by the interface layer.
- the application is not bound to a particular interface.

Reason about the state of the use case:

- As all the system events belonging to a particular use case are assigned to a single class, it is easier to control the sequence of events that may be imposed by a use case (e.g. MakePayment cannot occur until EndSale has occurred).

LOW COUPLING

How strongly are the objects connected to each other?

Coupling = object depending on other object.

When the independent element changes, it affects the dependent one.

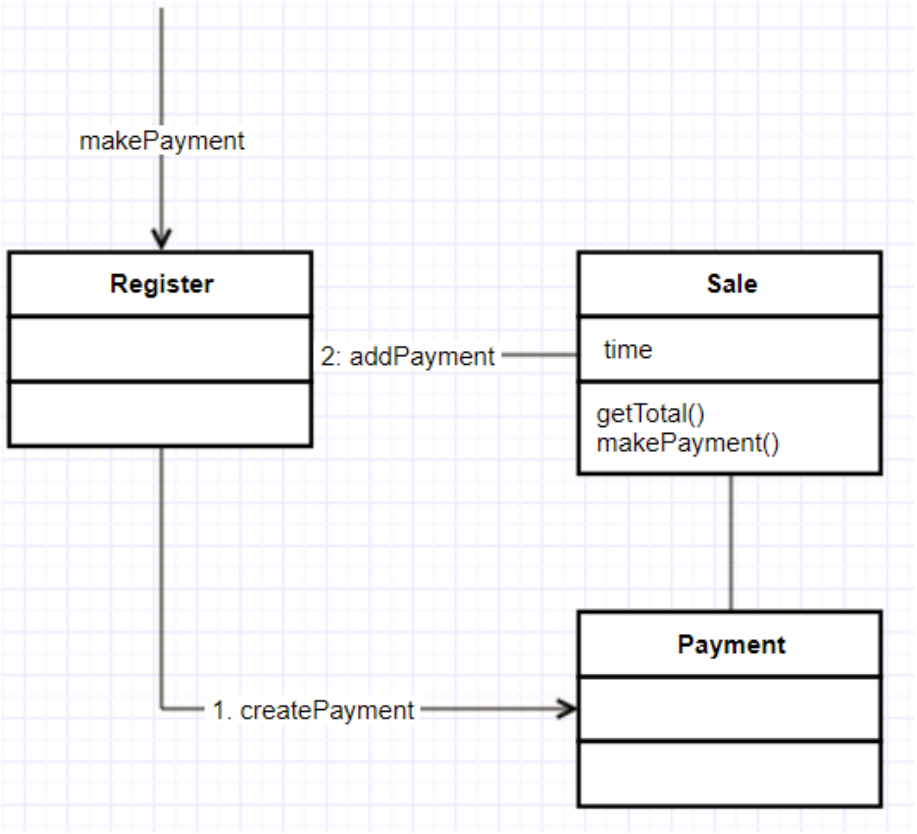
Prefer low coupling – assign responsibilities so that coupling remains low.

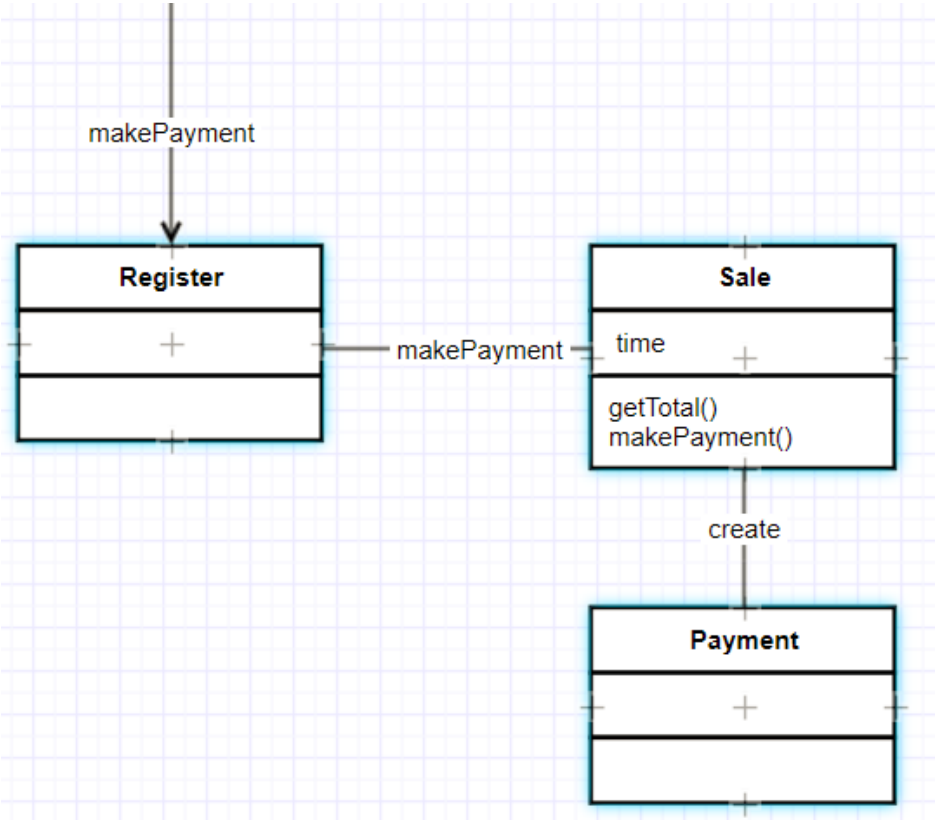
COUPLING

TypeX depends on TypeY if

- TypeX has an **attribute that refers** to a TypeY instance, or TypeY itself.
- TypeX has a **method which references** an instance of TypeY, or TypeY itself, by any means. (Typically include a parameter or local variable of type TypeY, or the returned object is an instance of TypeY.)
- TypeX is a direct or indirect **subclass** of TypeY.
- TypeY is an interface, and TypeX **implements** that interface.

WHICH IS BETTER COUPLED?





MEASURING COUPLING

```
class Person
{
    public string Name { get; set; }
    public int Age { get; set; }
    public double Salary { get; set; }
}
```

Code Metrics Results

Hierarchy	Class Coupling
ConsoleApplication6	0
ConsoleApplicatior	0
Person	0

```
class Person
{
    public string Name { get; set; }
    public int Age { get; set; }
    public double Salary { get; set; }
}

class PersonStuff
{
    void DoSomething()
    {
        Person myPerson = new Person();
        myPerson.Age = 23;
        myPerson.Name = "Bubba";
        myPerson.Salary = 20.34;
    }
}
```

Code Metrics Results

Hierarchy	Class Coupling
ConsoleApplication6 (D	1
ConsoleApplication6	1
Person	0
PersonStuff	1
DoSomething()	1
PersonStuff()	0

```
class PersonStuff
{
    Person myPerson = new Person();

    void DoSomething()
    {
        myPerson.Age = 23;
        myPerson.Name = "Bubba";
        myPerson.Salary = 20.34;
    }
}
```

Code Metrics Results

Hierarchy	Class Coupling
ConsoleApplication6 (D	1
ConsoleApplication6	1
Person	0
PersonStuff	1
DoSomething()	1
PersonStuff()	1

[https://blogs.msdn.microsoft.com/zainnab/2011/05/25/code-metrics-class-coupling/]

HIGH COHESION

How are the operations of any element functionally related?

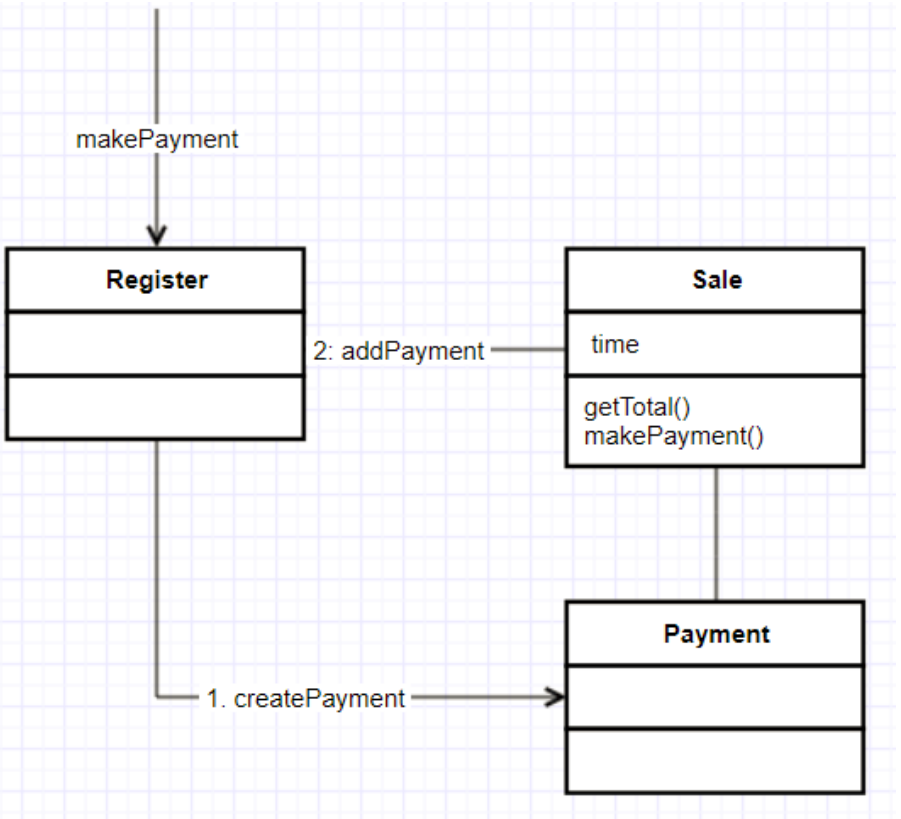
Related responsibilities are placed into one manageable unit.

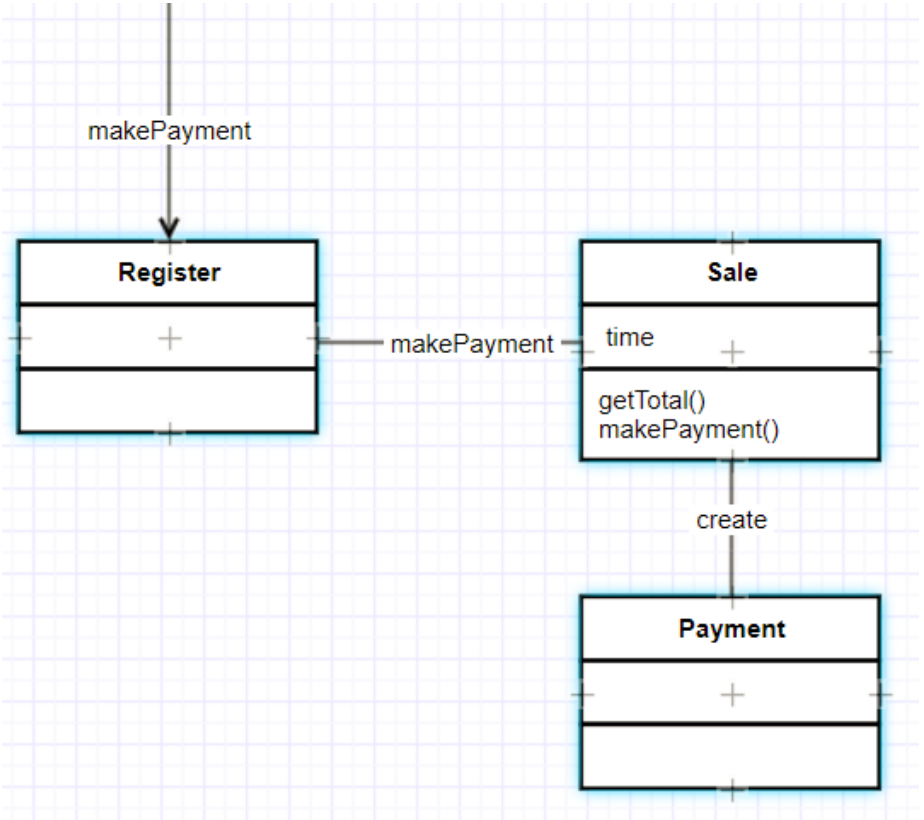
Correlated to SRP!

Benefits

- Easily understandable and maintainable.
- Code reuse
- Low coupling

COHESIVE?


makePayment
Register
2: addPayment
Sale
time
getTotal()
makePayment()
Payment
1. createPayment


makePayment
Register
makePayment
Sale
time
getTotal()
makePayment()
create
Payment

LACK OF COHESION (LCOM)

LCOM measures the dissimilarity of methods in a class by instance variable or attributes.

- *Functional cohesion* - the design unit (module) performs a single well-defined function or achieves a single goal.
- *Sequential cohesion* - the design unit performs more than one function, but these functions occur in an order prescribed by the specification, i.e. they are strongly related.
- *Communication cohesion* - a design unit performs multiple functions, but all are targeted on the same data.

LCOM CONT'D

- *Procedural cohesion* - a design unit performs multiple functions that are procedurally related. The code in each module represents a single piece of functionality defining a control sequence of activities.
- *Temporal cohesion* - a design unit performs more than one function, and they are related only by the fact that they must occur within the same time span (ex. a design that combines all data initialization into one unit and performs all initialization at the same time even though it may be defined and utilized in other design units).
- *Logical cohesion* - a design unit that performs a series of similar functions (ex. the Java class java.lang.Math)

LCOM4

LCOM4 measures the number of *"connected components"* in a class.

A connected component is a set of related methods (and class-level variables).

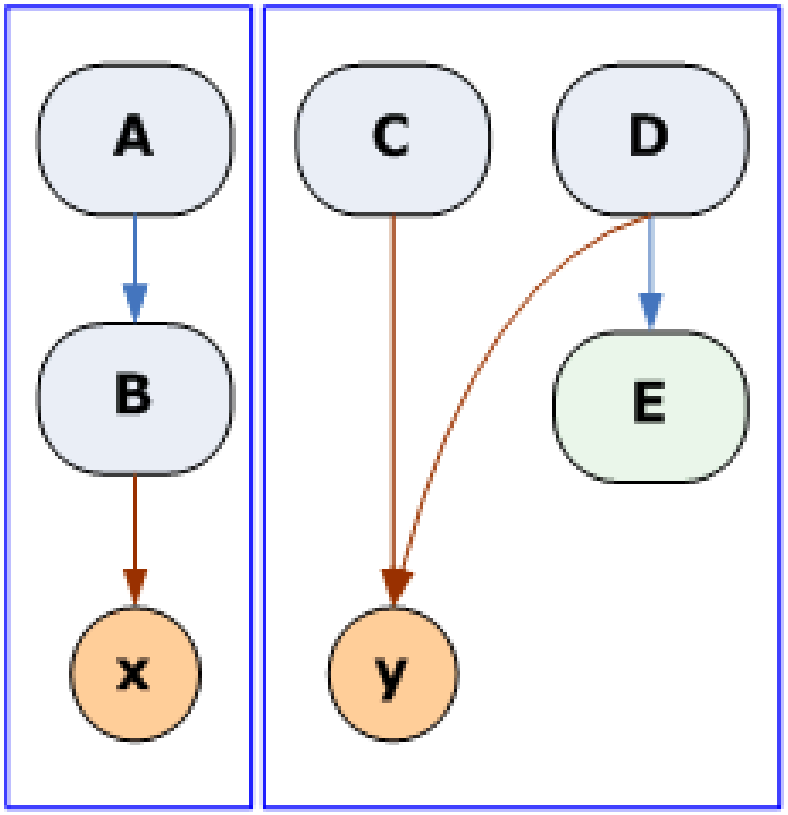
Methods **a** and **b** are related if:

- they both access the same class-level variable, or
- **a** calls **b**, or **b** calls **a**.

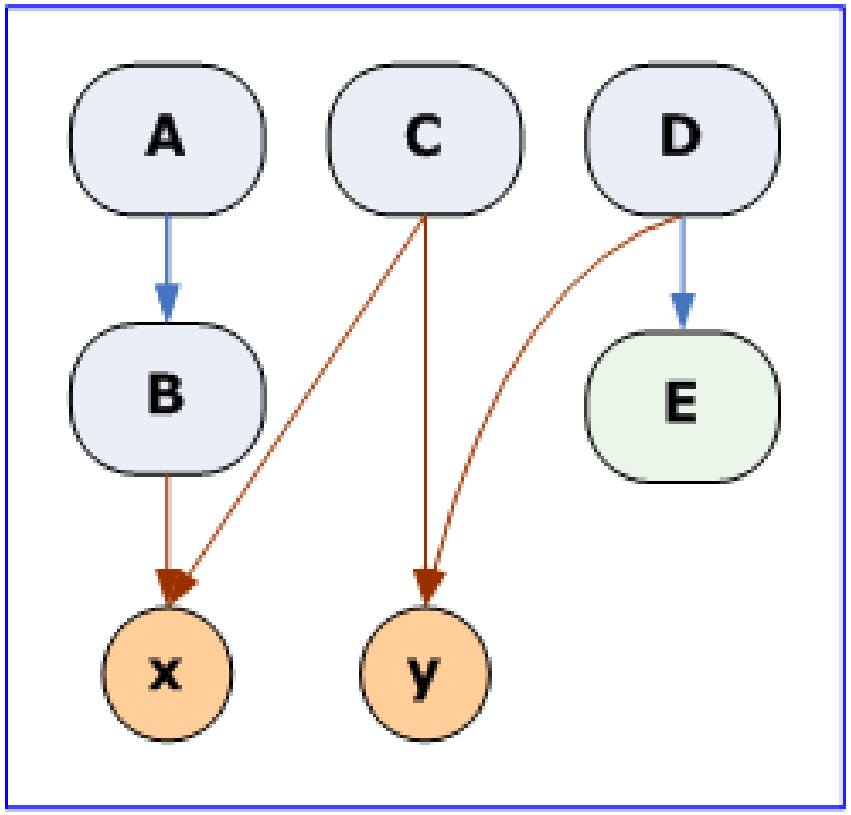
There should be only one connected component in each class.

If there are 2 or more components, the class should be split into so many smaller classes.

LCOM4



LCOM4 = 2



LCOM4 = 1

LAW OF DEMETER

Weak Form

Inside of a method M of a class C, data can be accessed and messages can be sent to only the following objects:

- **this** and **super**
- **data members (attributes)** of class C
- **parameters** of the method M
- **objects created** within M
  - by calling directly a constructor
  - by calling a method that creates the object
- **global variables**

Strong Form

In addition to the Weak Form, you are not allowed to access directly inherited members

LOD EXAMPLE

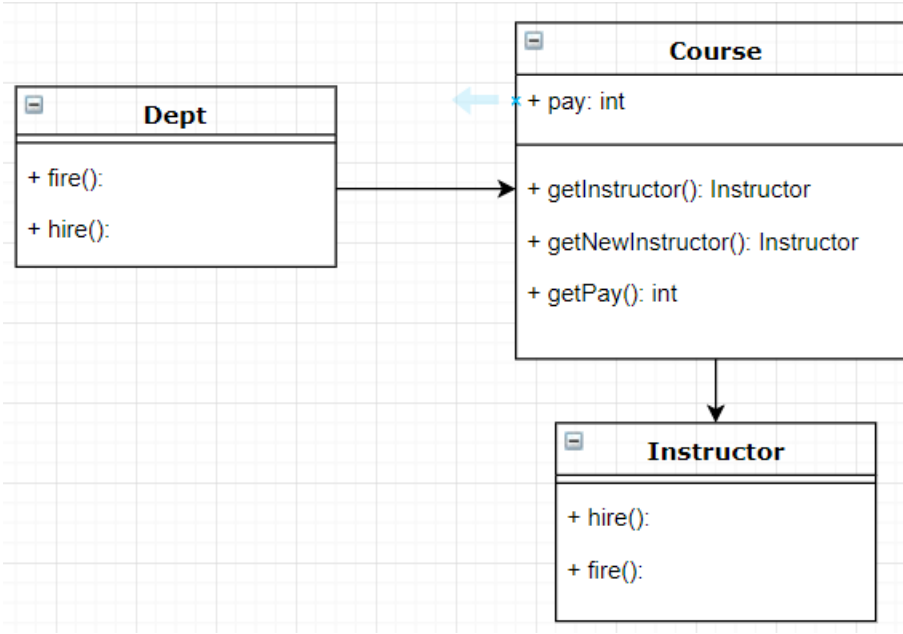
```
class Demeter {
        private A a;

        public void example(B b)
        {
                C c;
                c = func();
                b.invert();
                a = new A();
                a.setActive();
                c.print();
        }
}
```

passed parameters

attribute

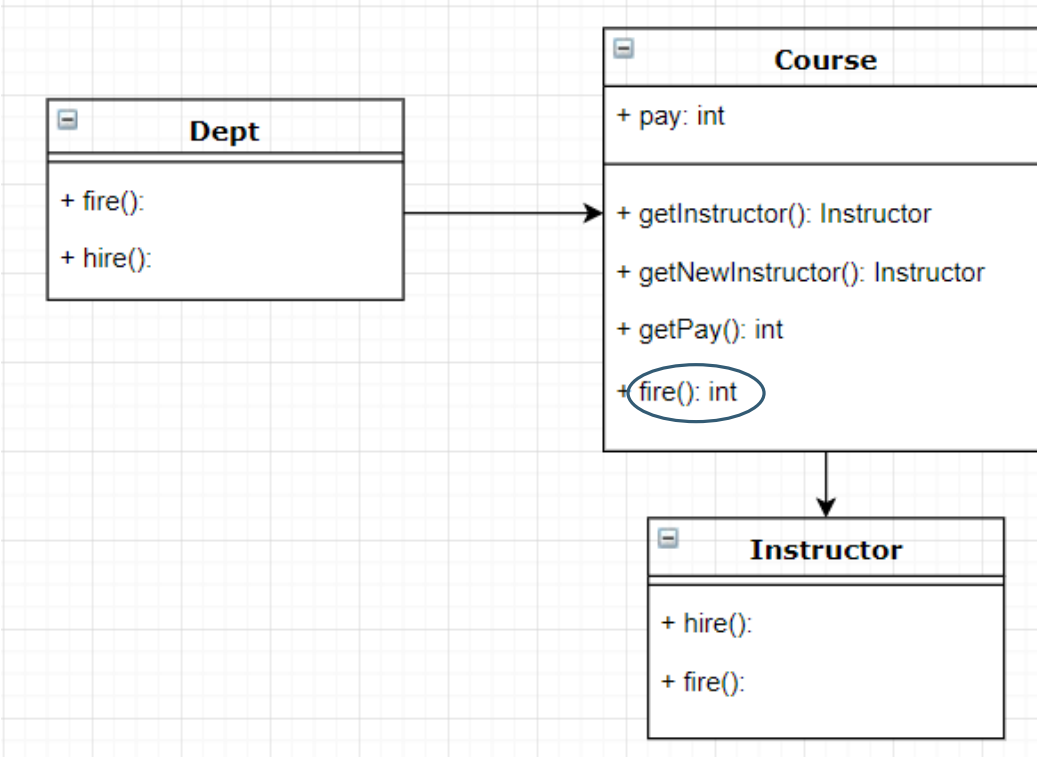
local variable

LOD COUNTER EXAMPLE




```
class Course
{
    Instructor boring = new Instructor();
    int pay = 5;
    public Instructor getInstructor() { return boring; }
    public Instructor getNewInstructor() {return new Instructor(); }
    public int getPay() {return pay; }
}

class Dept {
 Course test = new Course();
 public void fire() { test.getInstructor().fire(); }
 public void hire() { test.getNewInstructor().hire(); }
 public int raisePay() { return test.getpay() + 10;}
}
```

LOD GOOD EXAMPLE




```
class Course {
 Instructor boring = new Instructor();
 int pay = 5;
 public Instructor fire(){ boring.fire(); }
 public Instructor getNewInstructor() { return new Instructor();}
 public int getPay() { return pay ; }
}

class Dept {
 Course test = new Course();
 public void fire() {test.fire();}
      public void hire() {test.getNewInstructor().hire();}
      public int raisePay() { return  test.getpay() + 10;}
}
```

LOD FOR CHILDREN

You can play with yourself.

You can play with your own toys

You can play with toys that were given to you.

You can play with toys you've made yourself.

LOD BENEFITS

Coupling Control

- reduces data coupling

Information hiding

- prevents from retrieving subparts of an object

Information restriction

- restricts the use of methods that provide information

Few Interfaces

- restricts the classes that can be used in a method

Explicit Interfaces

- states explicitly which classes can be used in a method

ACCEPTABLE LOD VIOLATIONS

If optimization requires violation

- Speed or memory restrictions

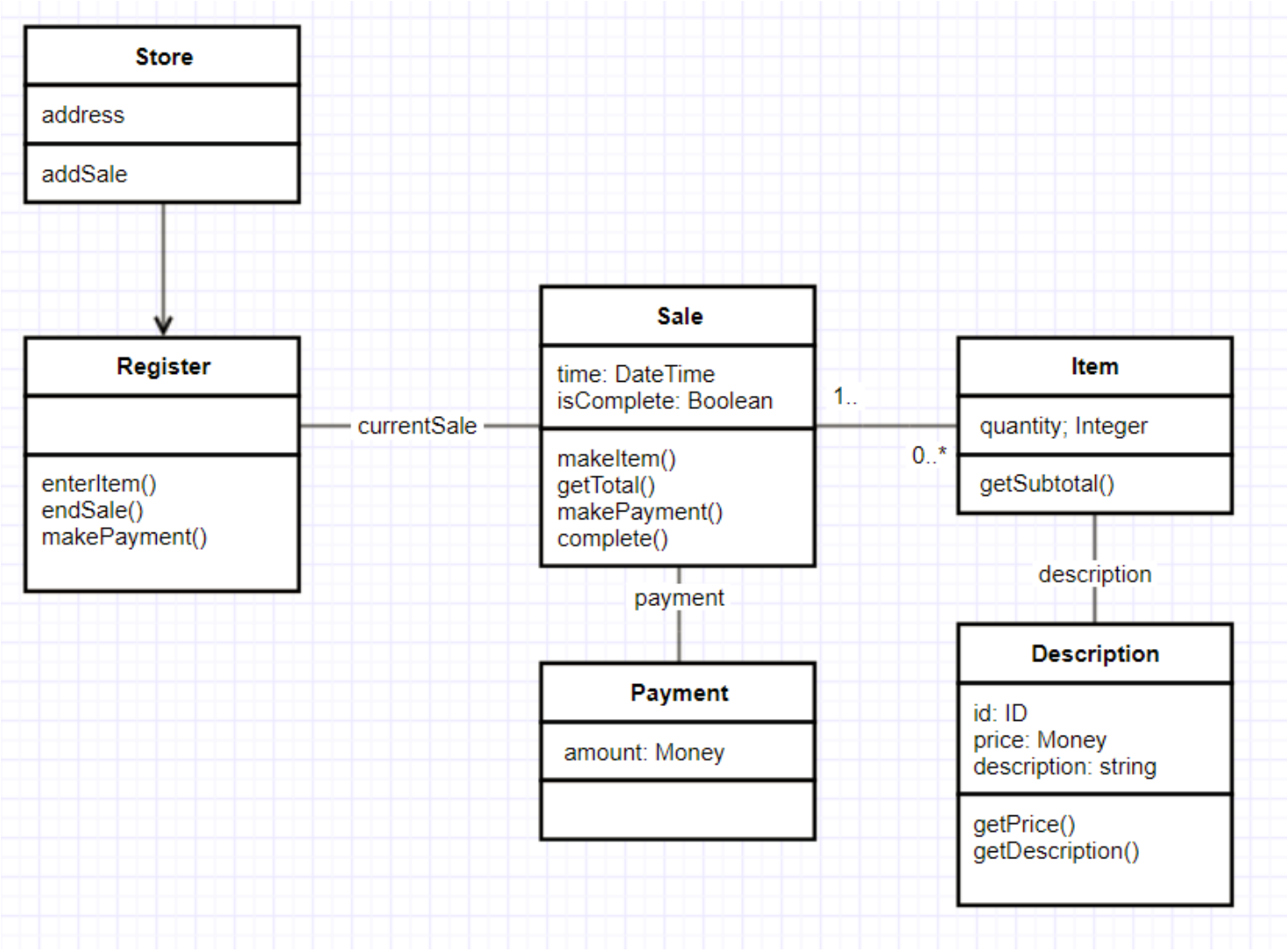
If module accessed is a fully stabilized "Black Box"

- No changes to interface can reasonably be expected due to extensive testing, usage, etc.

Otherwise, do not violate this law!!

- Long-term costs will be very prohibitive

POS FINAL DESIGN



HIGHER-LEVEL DESIGN

Dealing with *large-scale systems*

- team of developers, rather than an individual

Classes are a valuable but not sufficient mechanism

- too *fine-grained* for organizing a large scale design
- need mechanism that impose a higher level of order

Packages

- a logical grouping of declarations that can be imported in other programs
- containers for a group of classes (UML)
- reason at a higher-level of abstraction

ISSUES OF HIGHER-LEVEL DESIGN

Goal

- *partition* the classes in an application according to some *criteria* and then *allocate* those partitions to packages

Issues

- What are the best partitioning criteria?
- What principles govern the design of packages?
  - *creation* and *dependencies* between packages

Approach

- Define principles that govern package design
  - the creation and interrelationship and use of packages

PRINCIPLES OF OO HIGHER-LEVEL DESIGN

Cohesion Principles

- Reuse/Release Equivalency Principle (REP)
- Common Reuse Principle (CRP)
- Common Closure Principle (CCP)

Coupling Principles

- Acyclic Dependencies Principle (ADP)
- Stable Dependencies Principle (SDP)
- Stable Abstractions Principle (SAP)

WHAT IS REALLY REUSABILITY ?

Does copy-paste mean reusability?

- Disadvantage: **You** own that copy!
  - you must change it, fix bugs.
  - eventually the code diverges

Martin's Definition:

- *I reuse code if, and only if, I never need to look at the source-code*
- treat reused code like a *product* $\Rightarrow$ don't have to maintain it

Clients (re-users) may decide to use a newer version of a component release

REUSE/RELEASE EQUIVALENCY PRINCIPLE (REP)

The granule of reuse is the granule of release. *Only components that are released through a tracking system can be efficiently reused.* [R. Martin]

Either all the classes in a package are reusable or none of it is! [R. Martin]

WHAT DOES THIS MEAN?

Reused code = product

- Released, named and maintained by the producer.

Programmer = client

- Doesn't have to maintain reused code
- Doesn't have to name reused code
- May choose to use an older/newer release

THE COMMON REUSE PRINCIPLE

All classes in a package [library] should be reused together. If you reuse one of the classes in the package, you reuse them all. [R.Martin]

If I depend on a package, I want to depend on every class in that package! [R.Martin]

WHAT DOES THIS MEAN?

Criteria for grouping classes in a package:

- Classes that tend to be **reused** together.

Packages have physical representations (shared libraries, DLLs, assembly)

- Changing just one class in the package => re-release the package => revalidate the application that uses the package.

COMMON CLOSURE PRINCIPLE (CCP)

The classes in a package should be closed against the same kinds of changes.

A change that affects a package affects all the classes in that package

[R. Martin]

WHAT DOES THIS MEAN?

Another criteria of grouping classes: **Maintainability**!

- Classes that tend to change together for the same reasons
- Classes highly dependent

SRP at packages level

REUSE VS. MAINTENANCE

REP and CRP makes life easier for **reuser**

- packages very small

CCP makes life easier for **maintainer**

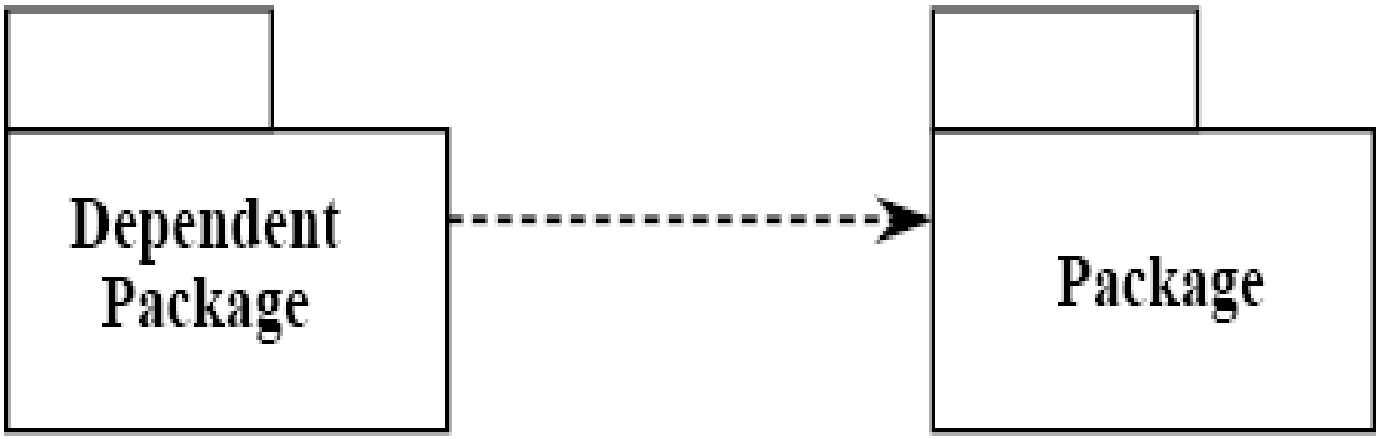
- larger packages

Packages are not fixed in stone

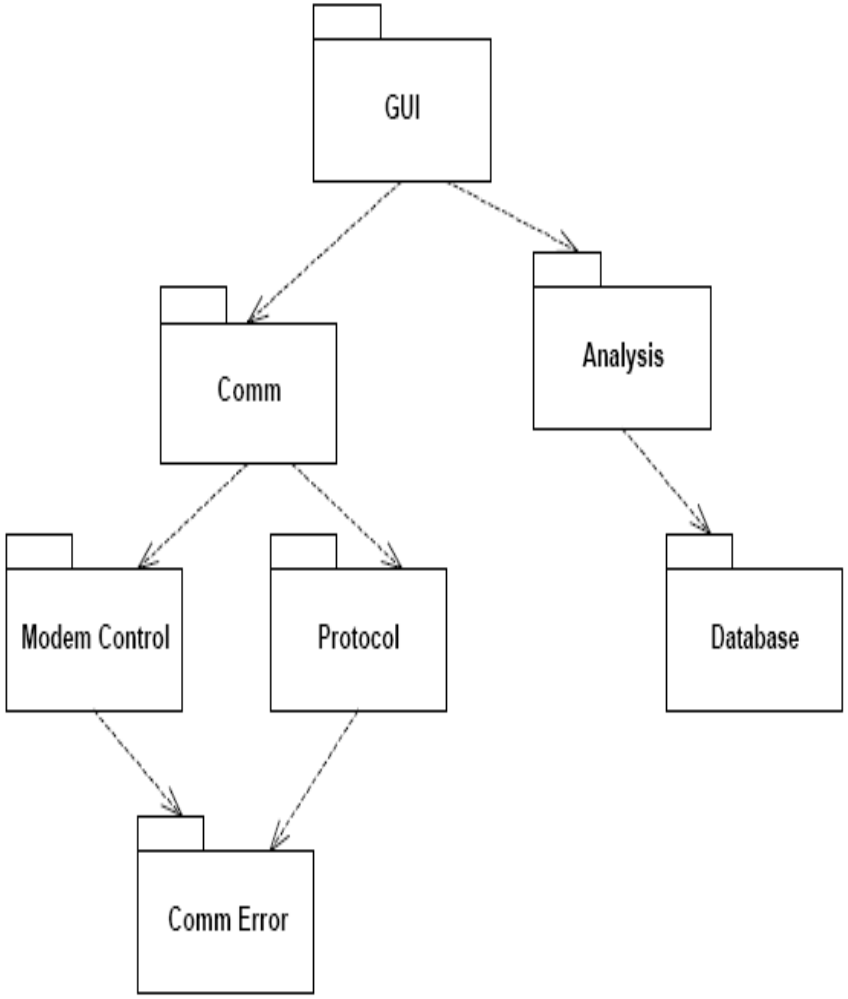
- early in project focus on CCP
- later when architecture stabilizes: focus on REP and CRP

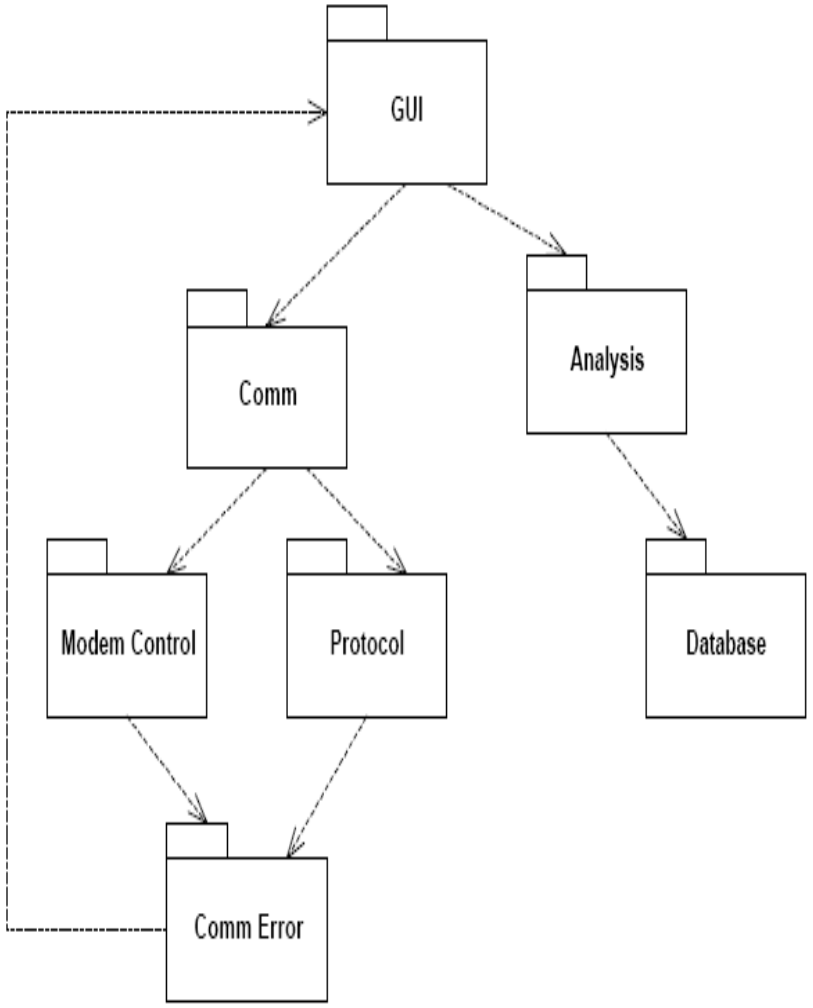
ACYCLIC DEPENDENCIES PRINCIPLES (ADP)

The dependency structure for released component must be a Directed Acyclic Graph (DAG).There can be no cycles. [R. Martin]

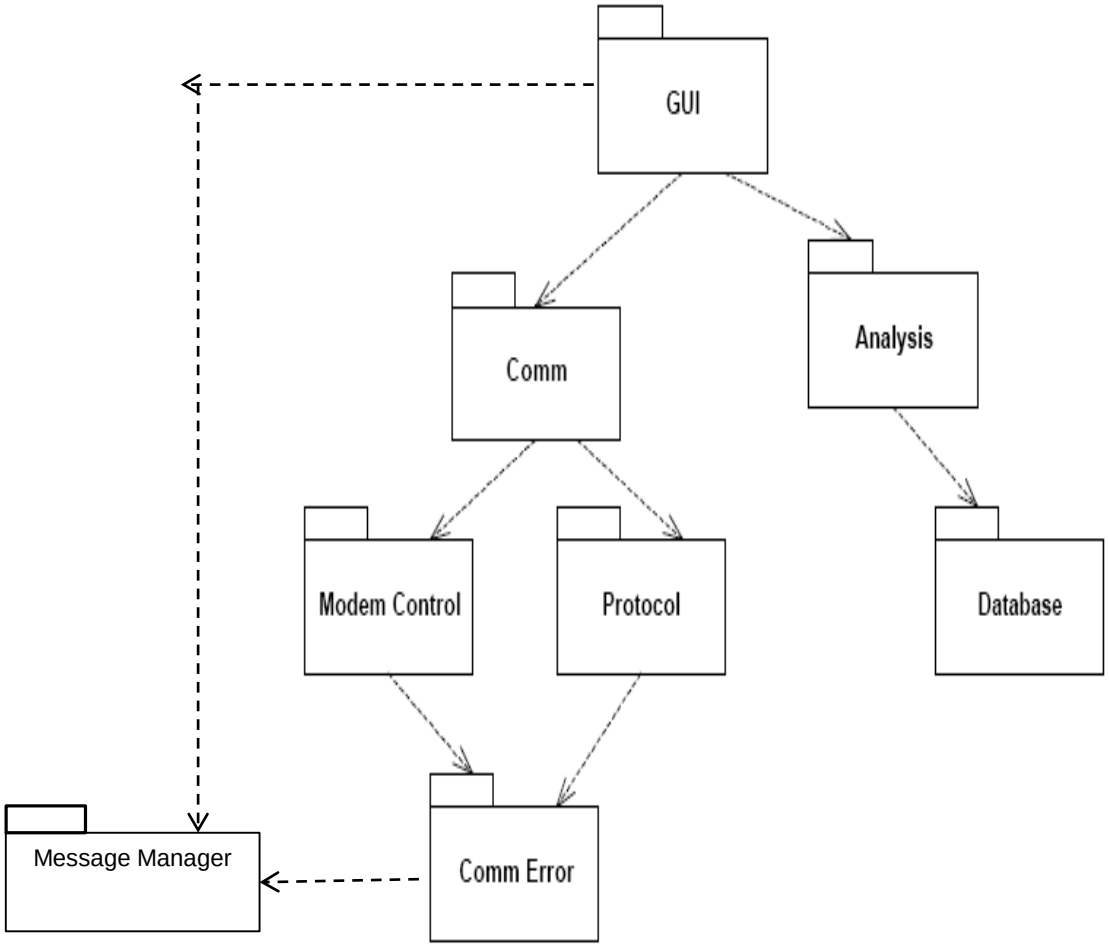


DEPENDENCY GRAPHS





BREAKING THE CYCLE

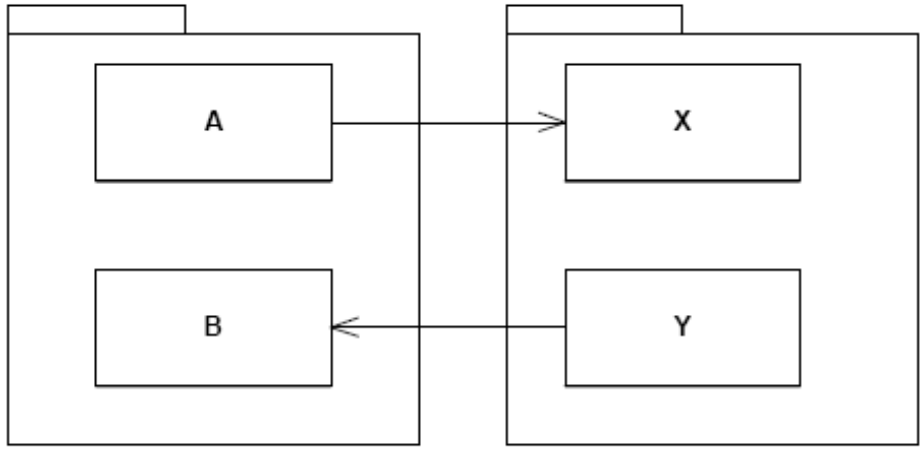


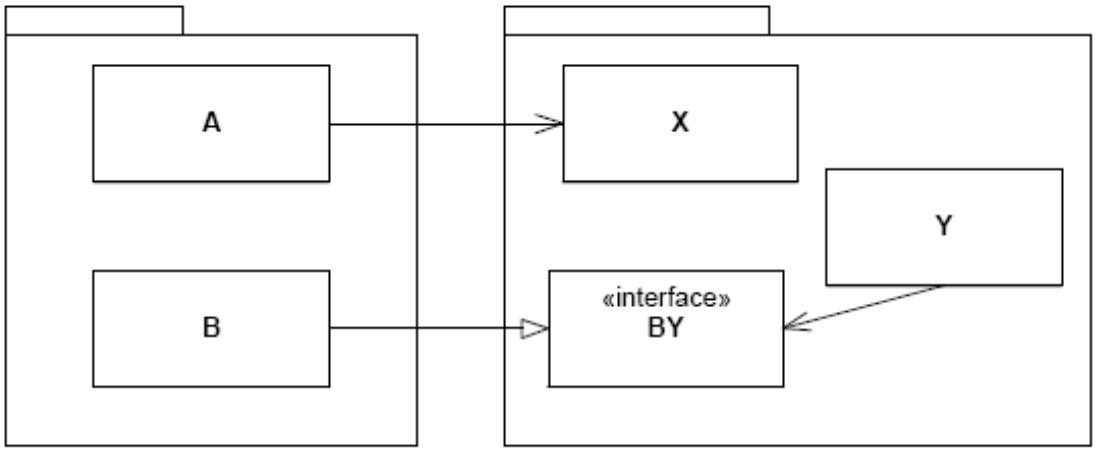
Take out of the GUI package the classes that Comm Error depend on

=> Add a new package (i.e. Message Manager)

BREAKING THE CYCLE

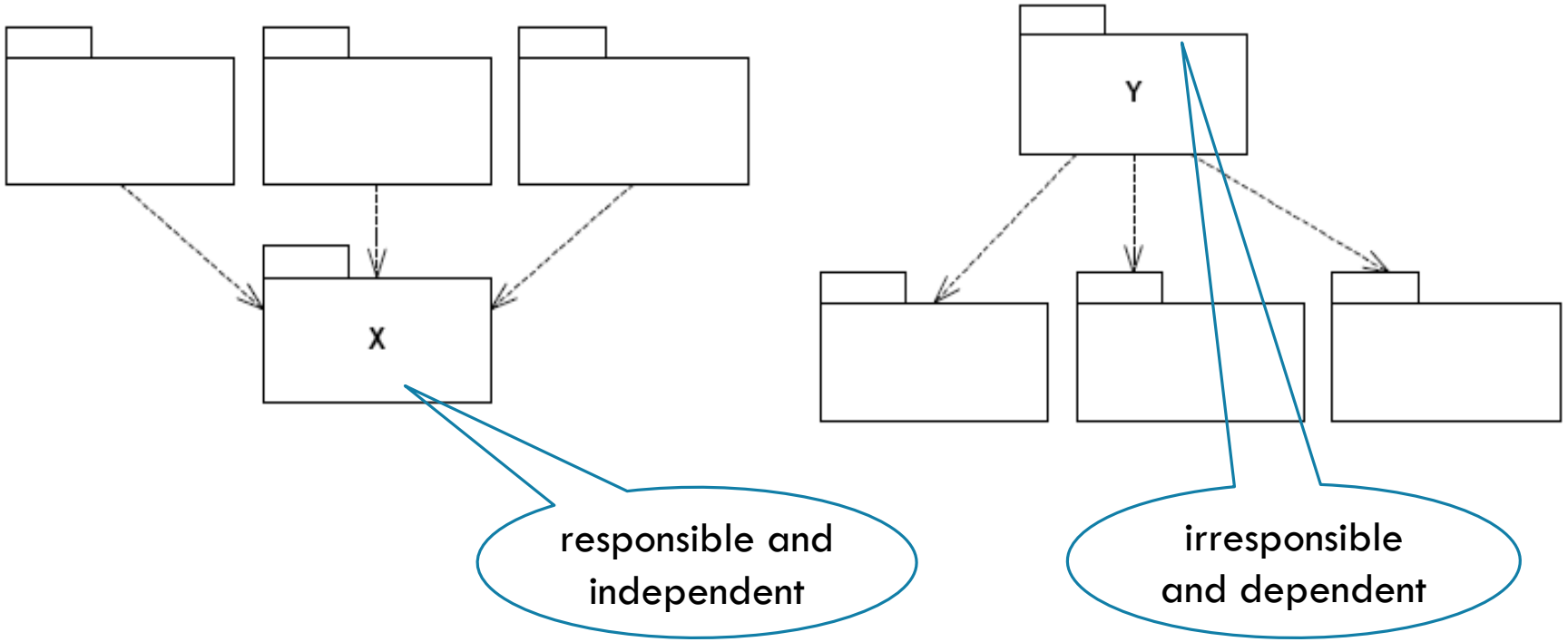
DIP + ISP





STABILITY

Stability is related to the amount of work in order to make a change.



Driven by Responsibility and Independence

STABILITY METRICS

Ca – Afferent coupling (incoming dependencies)

- How responsible am I?

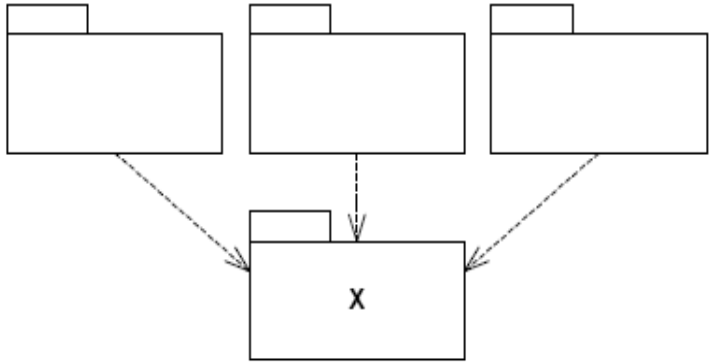
Ce – Efferent coupling (outgoing dependencies)

- How dependant am I?

Instability $I = Ce/(Ca+Ce)$

Example for X:

$Ca = 3, Ce = 0 \Rightarrow I = 0$ (very stable)



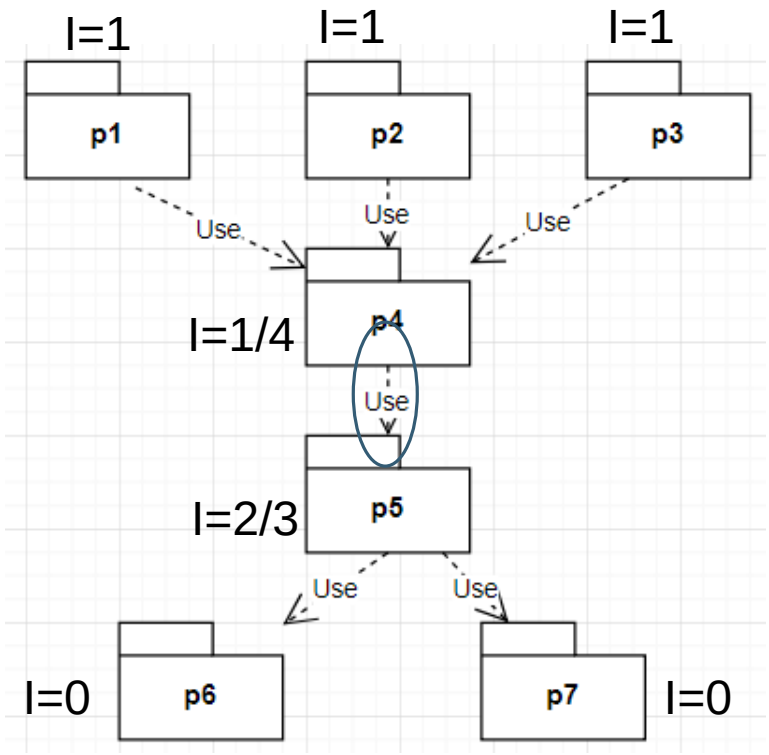
STABLE DEPENDENCY PRINCIPLE (SDP)

Depend in the direction of stability.

What does this mean?

- Depend upon packages whose I is lower than yours.

Counter-example



WHERE TO PUT HIGH-LEVEL DESIGN?

High-level architecture and design decisions don't change often

- shouldn't be volatile ⇒ place them in stable packages
- design becomes hard to change ⇒ *inflexible design*

How can a totally stable package (I = 0) be flexible enough to withstand change?

Answer: ***The Open-Closed Principle***

- Classes that can be extended without modifying them ⇒ Abstract Classes

STABLE ABSTRACTIONS PRINCIPLE (SAP)

Stable packages should be abstract packages.

What does this mean?

- Stable packages should be depended upon
- Flexible packages should be dependent
- OCP => Stable packages should be highly abstract

ABSTRACTNESS METRICS

Nc = number of classes in the package

Na = number of abstract classes in the package

Abstractness A = *Na*/*Nc*

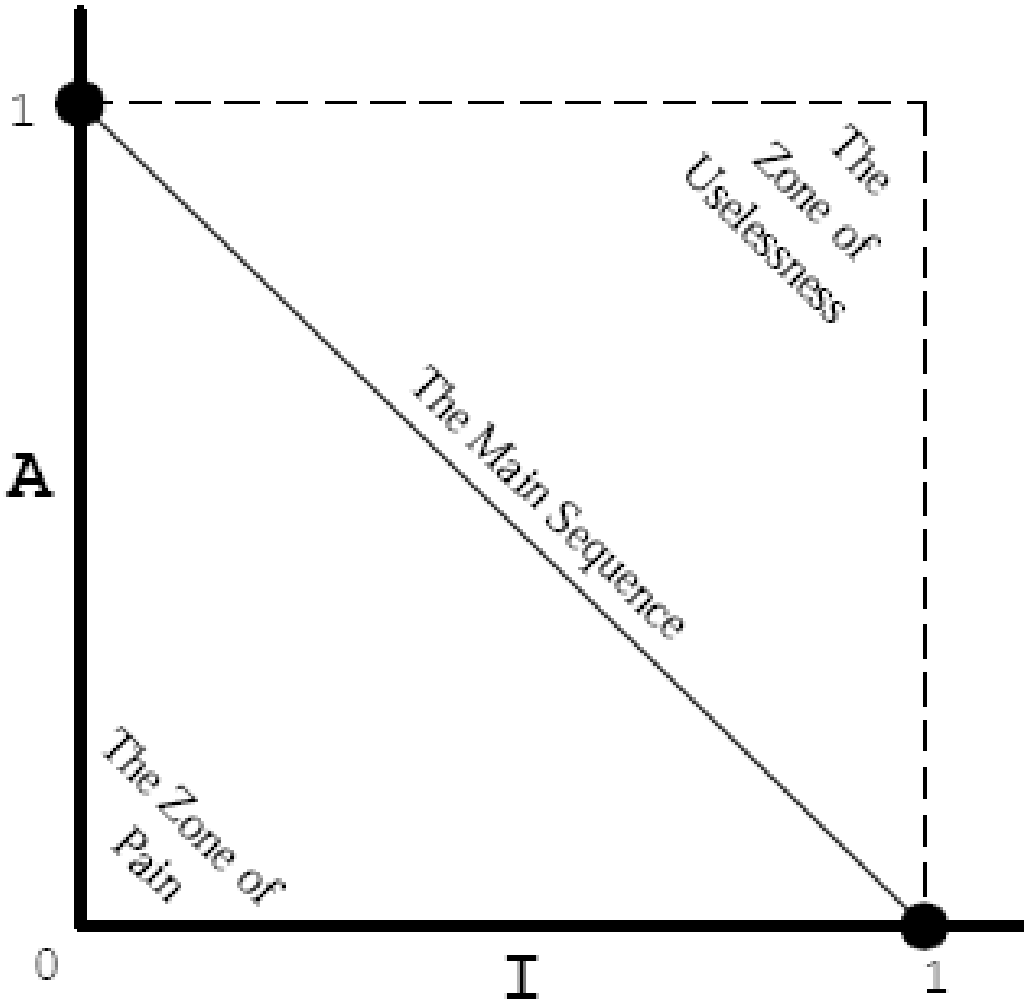
Example:

- *All classes are concrete Na* = 0 => A = 0

What about hybrid classes?

THE MAIN SEQUENCE

I should increase as *A* decreases



THE MAIN SEQUENCE

Zone of Pain

- highly stable and concrete ⇒ rigid
- famous examples:
  - database-schemas (volatile and highly depended-upon)
  - concrete utility libraries (instable but non-volatile)

Zone of Uselessness

- instable and abstract ⇒ useless
  - no one depends on those classes

Main Sequence

- maximizes the distance between the zones we want to avoid
- depicts the balance between abstractness and stability.

WRAP-UP

Principles for good class design related to

- Assigning Responsibilities (GRASP)
- Package design
  - Coupling
  - Cohesion