面向对象的模块化

刘钦

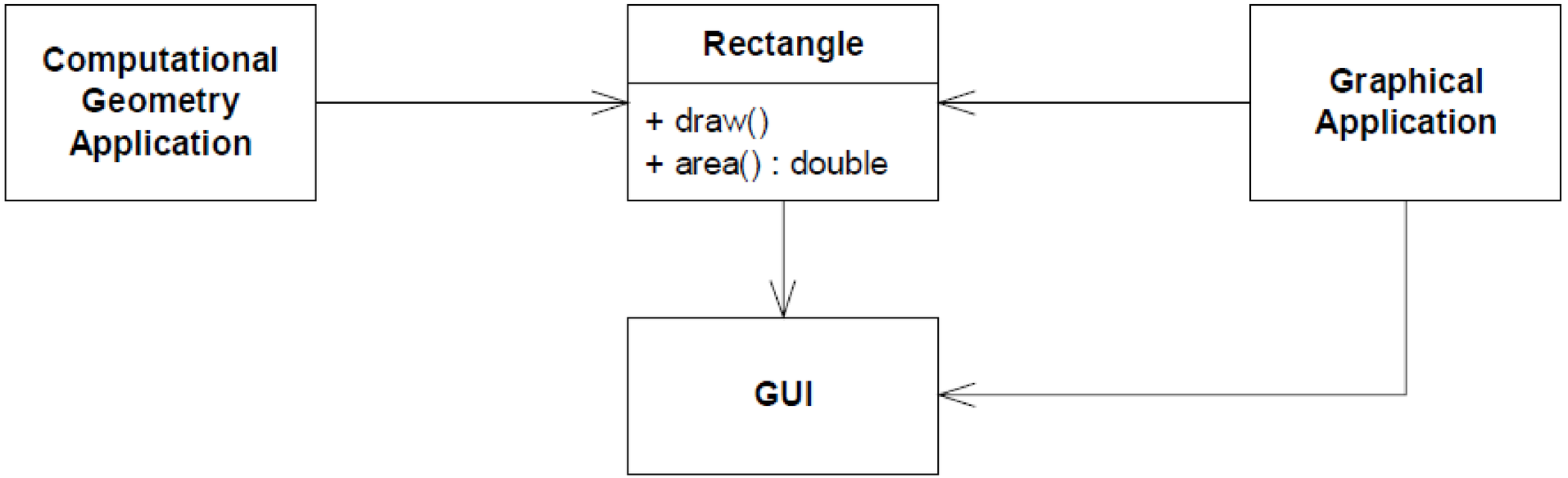


Figure 9-1

课前练习

Outline

- 面向对象中的模块与耦合
- 访问耦合
- 继承耦合
- 内聚
- 耦合和内聚的度量

Module

- A piece of code
  - Methods
  - Class
  - Module(package)
- Coupling:
  - among pieces
- Cohesion:
  - internal a piece

Structural methods vs OO methods in Coupling

- Coupling
  - Coupling is the measure of the strength of association established by a connection from one module to another
- Structural methods
  - A connection is a reference to some label or address defined elsewhere
- OO methods
  - Component coupling （访问耦合）
  - Inheritance coupling （继承耦合）

降低耦合的设计原则

- 1: 《Global Variables Consider Harmful》
- 2: 《To be Explicit》
- 3: 《Do not Repeat》
- 4: Programming to Interface

Outline

- 面向对象中的模块与耦合
- 访问耦合
- 继承耦合
- 内聚
- 耦合和内聚的度量

表 14-1　访问耦合

类　型	耦　合　性	解　释	例　子
隐式访问	最高	B 既没在 A 的规格中出现，也没在实现中出现	Cascading Message
实现中访问		B 的引用是 A 方法中的局部变量	1）通过引入局部变量，避免 Cascading Message 2）方法中创建一个对象，将其引用赋予方法的局部变量，并使用
成员变量访问		B 的引用是 A 的成员变量	类的规格中包含所有需接口和供接口（需要特殊语言机制）
参数变量访问		B 的引用是 A 的方法的参数变量	类的规格中包含所有需接口和供接口（需要特殊语言机制）
无访问	最低	理论最优，无关联耦合，维护时不需要对方任何信息	完全独立

注：源自［Eder1992］。

访问耦合

Example: Consider the class EMPLOYEE as defined above with the additional instance variable **involvedInProject**, which references the project for which an employee is currently working, and the additional method **numberColleagues**, which returns the number of colleagues in the current project. The implementation of **numberColleagues** may be given as follows:

```
int numberColleagues () {
      return (involvedInProject->getProjectMembers->count - 1)
}
```

Cascading Message问题

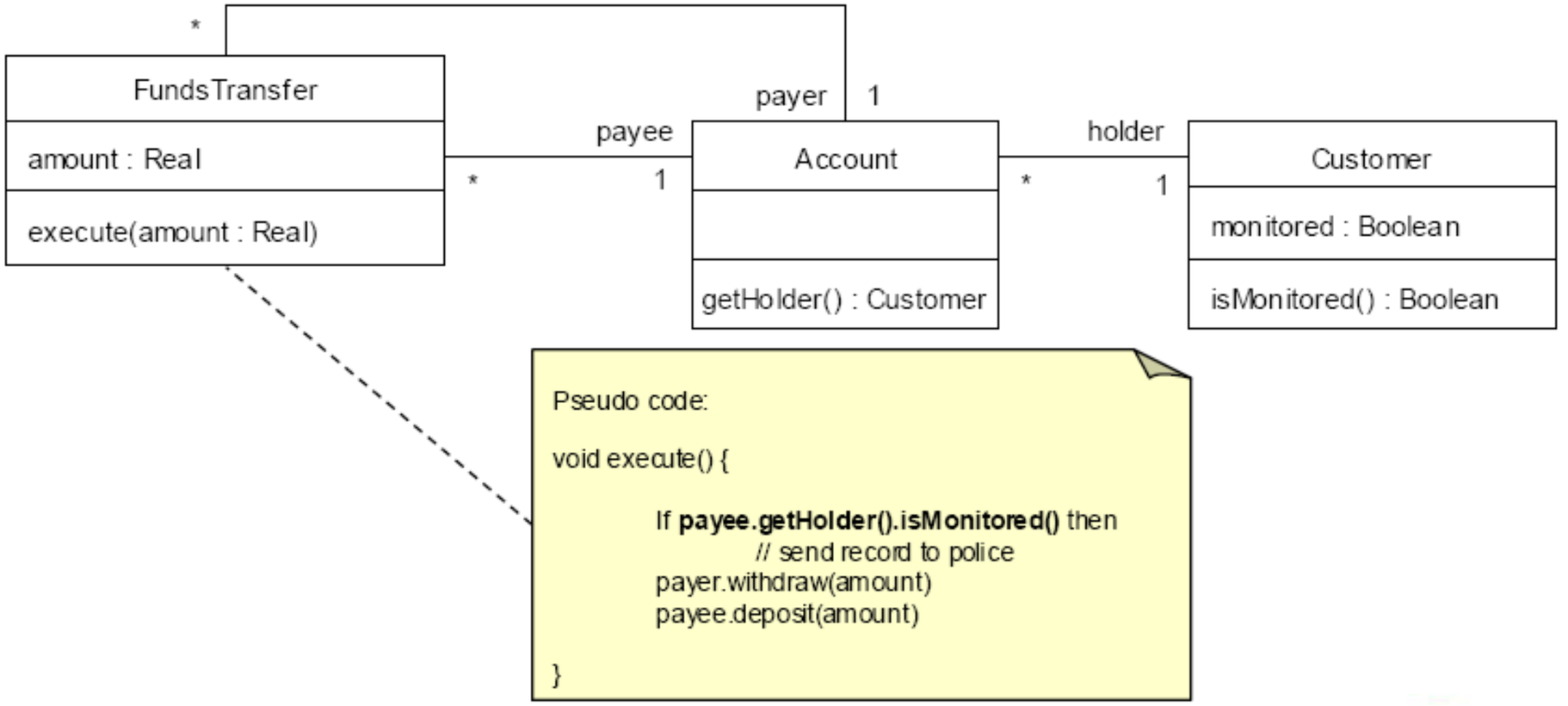
Example: Consider the previous example where the classes EMPLOYEE and SET⟨EMPLOYEE*⟩ are hidden coupled due to the implementation of the method numberColleagues. The implementation may be improved by disallowing cascading messages as follows:

```
int numberColleagues () {
        SET⟨EMPLOYEE*⟩ * projectMembers;
        projectMembers = involvedInProject->getProjectMembers;
        return (projectMembers->count - 1)
}
```

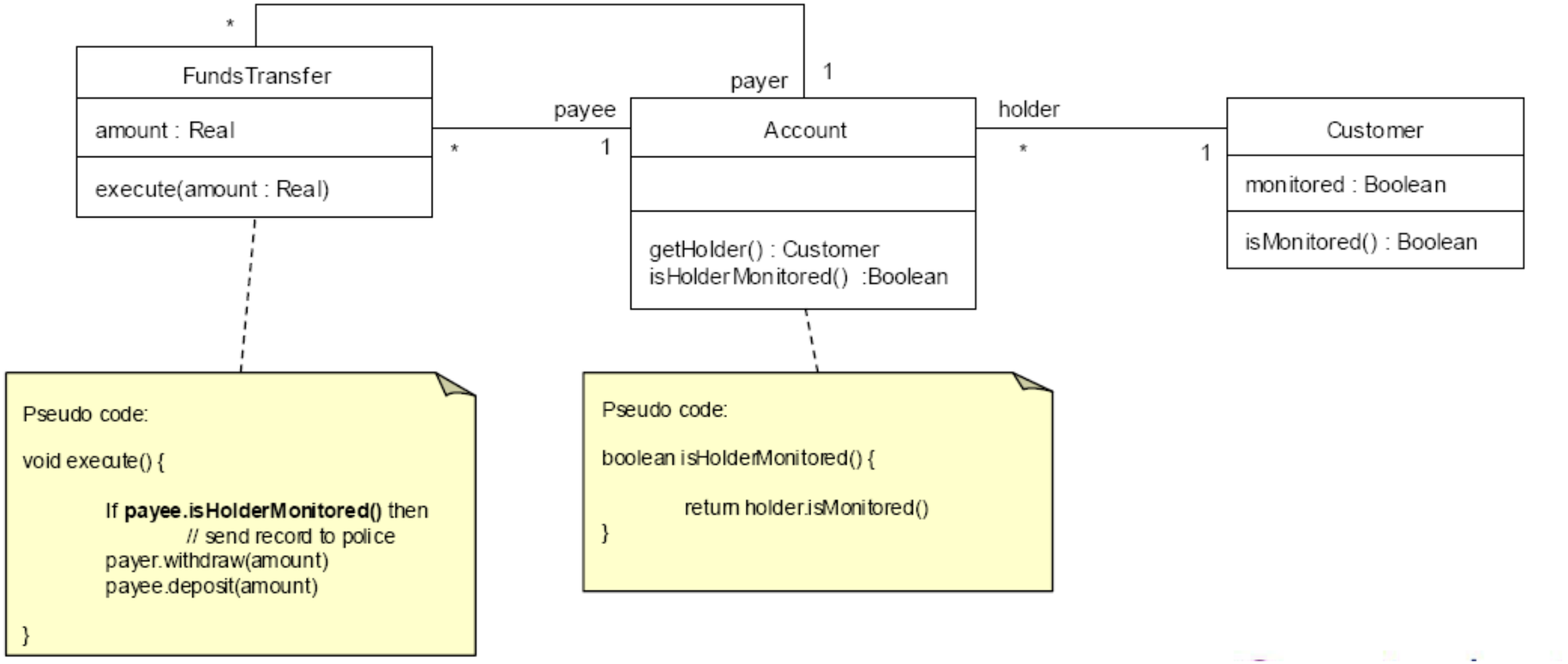
By introducing local variables and disallowing cascading messages the coupling between the classes EMPLOYEE and SET⟨EMPLOYEE*⟩ can be improved from hidden to scattered. □

解决方案一引入局部变量

Cascading Message问题案例

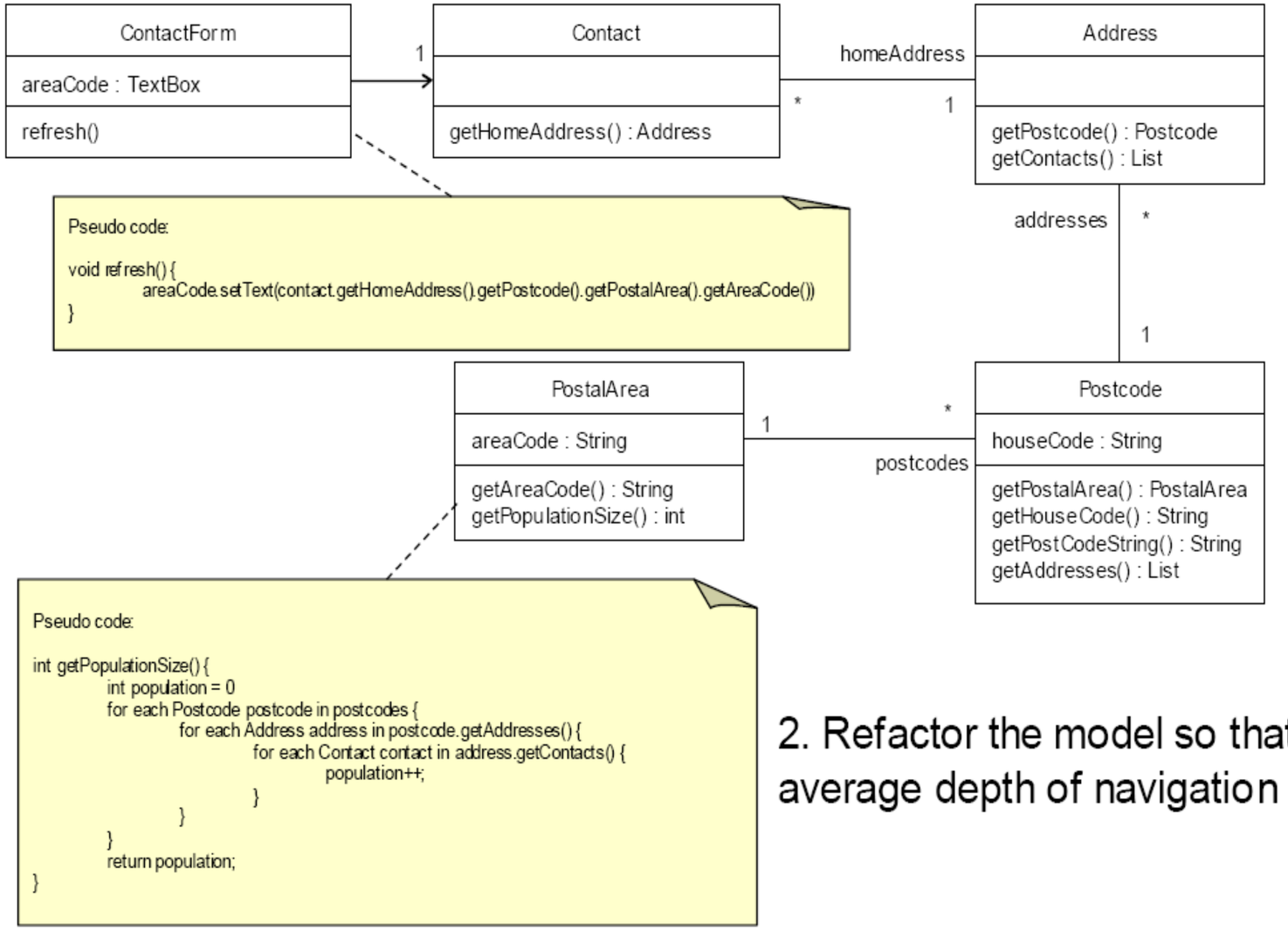


解决方案 — 委托


*
FundsTransfer
amount : Real
execute(amount : Real)
payer
1
payee
*
1
Account
getHolder() : Customer
isHolderMonitored() :Boolean
holder
*
1
Customer
monitored : Boolean
isMonitored() : Boolean
Pseudo code:
void execute() {
If payee.isHolderMonitored() then
// send record to police
payer.withdraw(amount)
payee.deposit(amount)
}
Pseudo code:
boolean isHolderMonitored() {
return holder.isMonitored()
}

Principles of Component Coupling

- Principle 5: The Law of Demeter
  - You can play with yourself.
  - You can play with your own toys, but you can't take them apart
  - You can play with toys that were given to you.
  - You can play with toys you've made yourself.



2. Refactor the model so that the average depth of navigation is 1

问题案例

Principles of Component Coupling

- Principle 4: Programming to Interface 面向接口编程
    - Programming to Required Interface, not only Suffered Interface
    - Design by Contract
        - Contract of Module/ Class
            - Required methods / Provided methods
        - Contract of Methods
            - PreCondition, PostCondition, Invariant

Example: In the previous example the classes EMPLOYEE and SET⟨EMPLOYEE*⟩ are scattered coupled. We may improve their coupling property to specified coupling by changing the specification of EMPLOYEE as follows:

```
class EMPLOYEE {
suffered interface:                    /* corresponds to public in C++ */
        int computeSalary ();
        int numberColleagues ();
        ...
required interface:                    /* not available in C++ */
        SET⟨EMPLOYEE*⟩* class PROJECT::getProjectMembers ();
        int class SET⟨EMPLOYEE*⟩::count ();
        ...
};
```

案例

Principles of Component Coupling

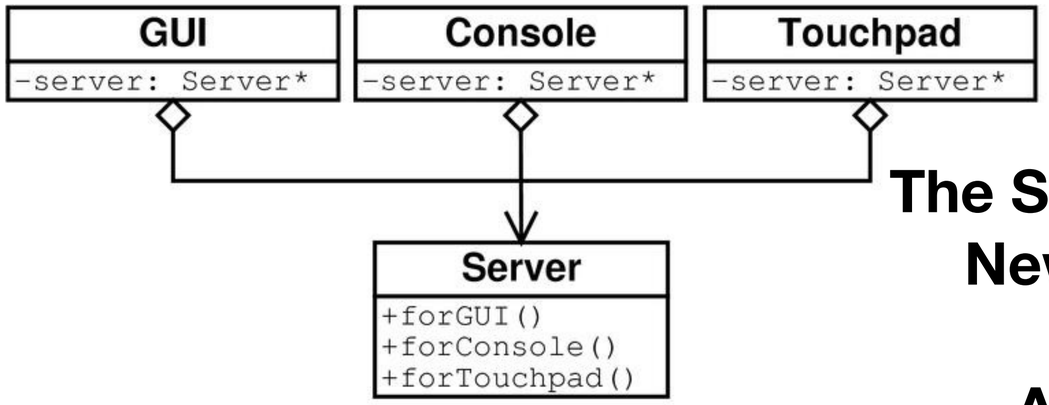
Clients should not be forced to depend upon interfaces that they do not use.
R. Martin, 1996

接口分离原则

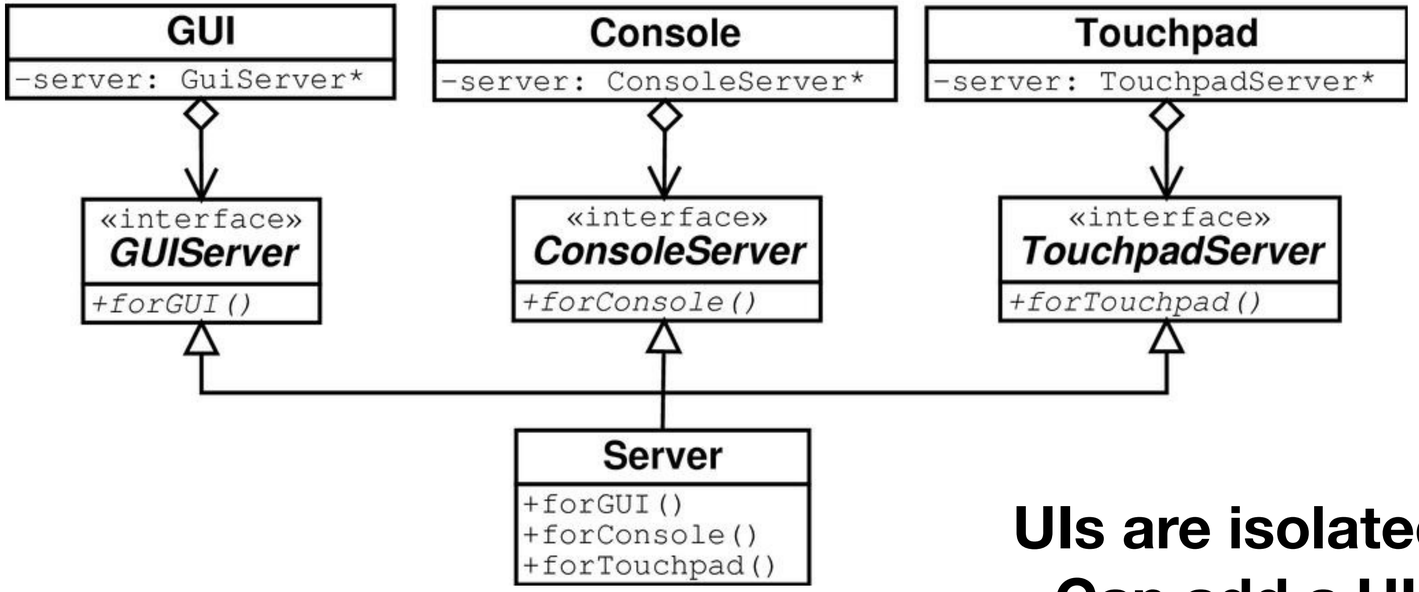
- Principles 6: Interface Segregation Principle(ISP)
  - Programming to Simpler Interface
- Many client-specific interfaces are better than one general purpose interface

Principles of Component Coupling —— ISP Explained

- Multipurpose classes
  - Methods fall in different groups
  - Not all users use all methods
- Can lead to unwanted dependencies
  - Clients using one aspect of a class also depend indirectly on the dependencies of the other aspects
- ISP helps to solve the problem
  - Use several client-specific interfaces

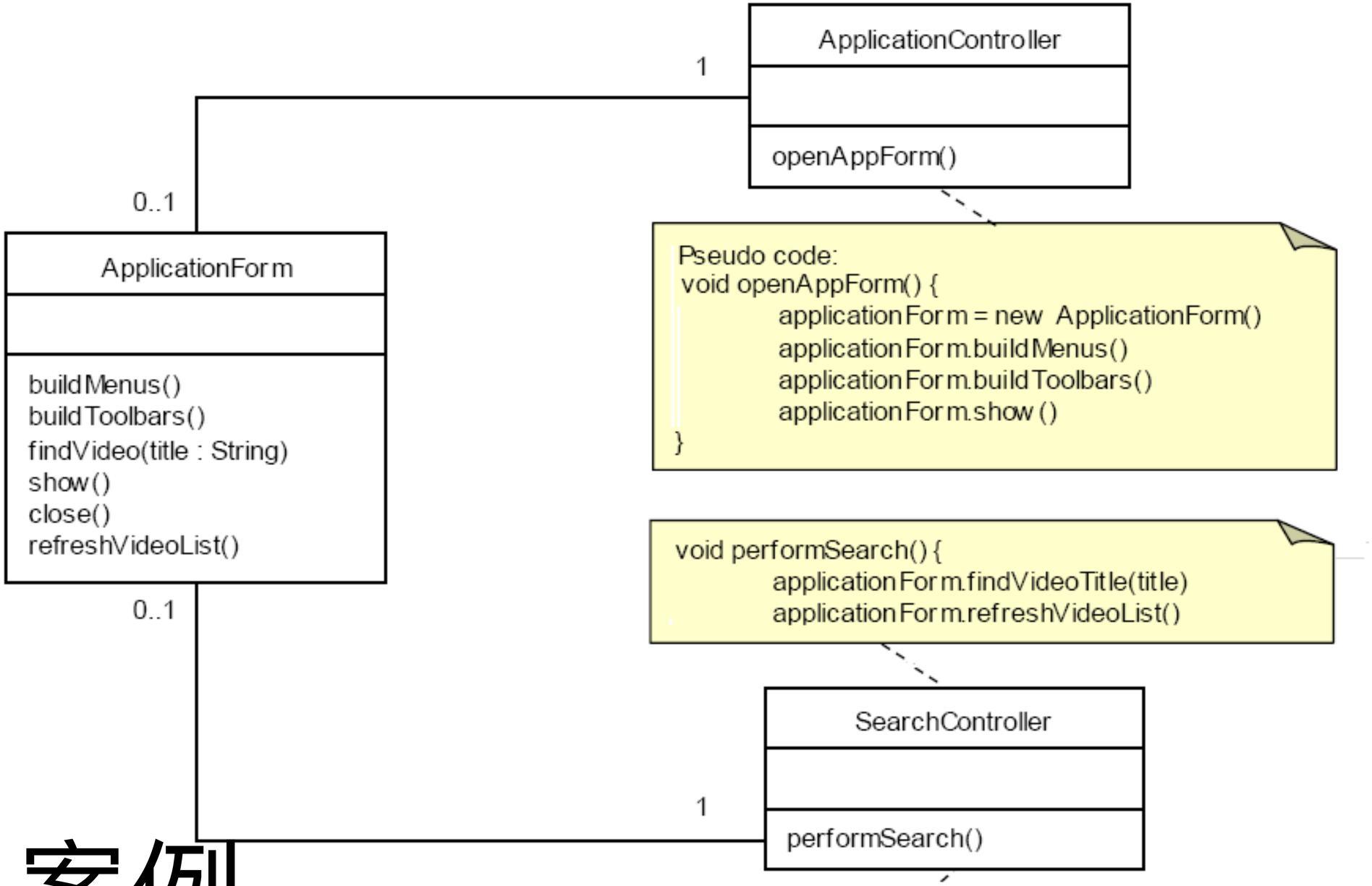


The Server "collects" interfaces
New UI → Server interface changes
All other UIs recompile



UIs are isolated from each other
Can add a UI with changes in Server → other UIs not affected

案例


ApplicationController
openAppForm()
1
0..1
ApplicationForm
buildMenus()
buildToolbars()
findVideo(title : String)
show()
close()
refreshVideoList()
0..1
Pseudo code:
void openAppForm() {
applicationForm = new ApplicationForm()
applicationForm.buildMenus()
applicationForm.buildToolbars()
applicationForm.show()
}
void performSearch() {
applicationForm.findVideoTitle(title)
applicationForm.refreshVideoList()
SearchController
performSearch()
1

案例

Outline

- 面向对象中的模块与耦合
- 访问耦合
- 继承耦合
- 内聚
- 耦合和内聚的度量

表 14-2　继承耦合

类　　型		耦　合　性	解　　释
修改（modification）	规格	最高	子类任意修改从父类继承回来的方法的接口
	实现		子类任意修改从父类继承回来的方法的实现
精化（refinement）	规格		子类只根据已经定义好的规则（语义）来修改父类的方法，且至少有一个方法的接口被改动
	实现		子类只根据已经定义好的规则（语义）来修改父类的方法，但只改动了方法的实现
扩展（extension）			子类只是增加新的方法和成员变量，不对从父类继承回来的任何成员进行更改
无（nil）		最低	两个类之间没有继承关系

继承耦合

Modification Inheritance Coupling

- Modifying without any rules and restricts
- Worst Inheritance Coupling
- If a client using a parent ref, the parent and child method are all needed
  - Implicit
  - There are two connections, more complex
- Harm to polymorphism

Example: Consider class STACK inheriting from class ARRAY. Since ARRAY is only used to implement STACK's internal data structure, and since the methods of ARRAY are semantically not meaningful when used with a stack (e.g., the method putAt of ARRAY does not exist for a stack) the methods of ARRAY are only inherited for private use but are deleted from the suffered, i.e., public interface of STACK. Thus STACK and ARRAY are signature modification coupled. To improve their coupling the definition of STACK should include an instance variable a with domain ARRAY instead of inheriting from ARRAY. □

问题案例

Refinement Inheritance Coupling

- defining new information
- the inherited information is only changed due to predefined rules
- If a client using a parent ref, the whole parent and refinement of child are needed
  - 1+connections
- Necessary!

```
class PERSON {
      [0..120] age;            /* for simplicity we assume */
      ...                      /* the existence of an enumeration type [0..120] */
public;                        /* and [15..65] */
      [0..120] getAge ();
      void setAge ([0..120] a);
      ...
}

class EMPLOYEE : public PERSON {
      [15..65] age;
      ...
public;
      [15..65] getAge ();
      void setAge ([15..65] a);
      ...
}
```

Since employees may only be active from 15 to 65 (at least in Austria) the subclass EMPLOYEE of class PERSON refines the signatures of the inherited access operations of **age** according to the covariant style. Thus, EMPLOYEE and PERSON are signature refinement coupled based on the covariant style.

Extension Inheritance Coupling

- the subclass only adds methods and instance variables but neither modifies nor refines any of the inherited ones
- If a client using a parent ref, only the parent is needed
    - 1 connection

Principles of Inherit Coupling

Principle 7: Liskov Substitution Principle (LSP)

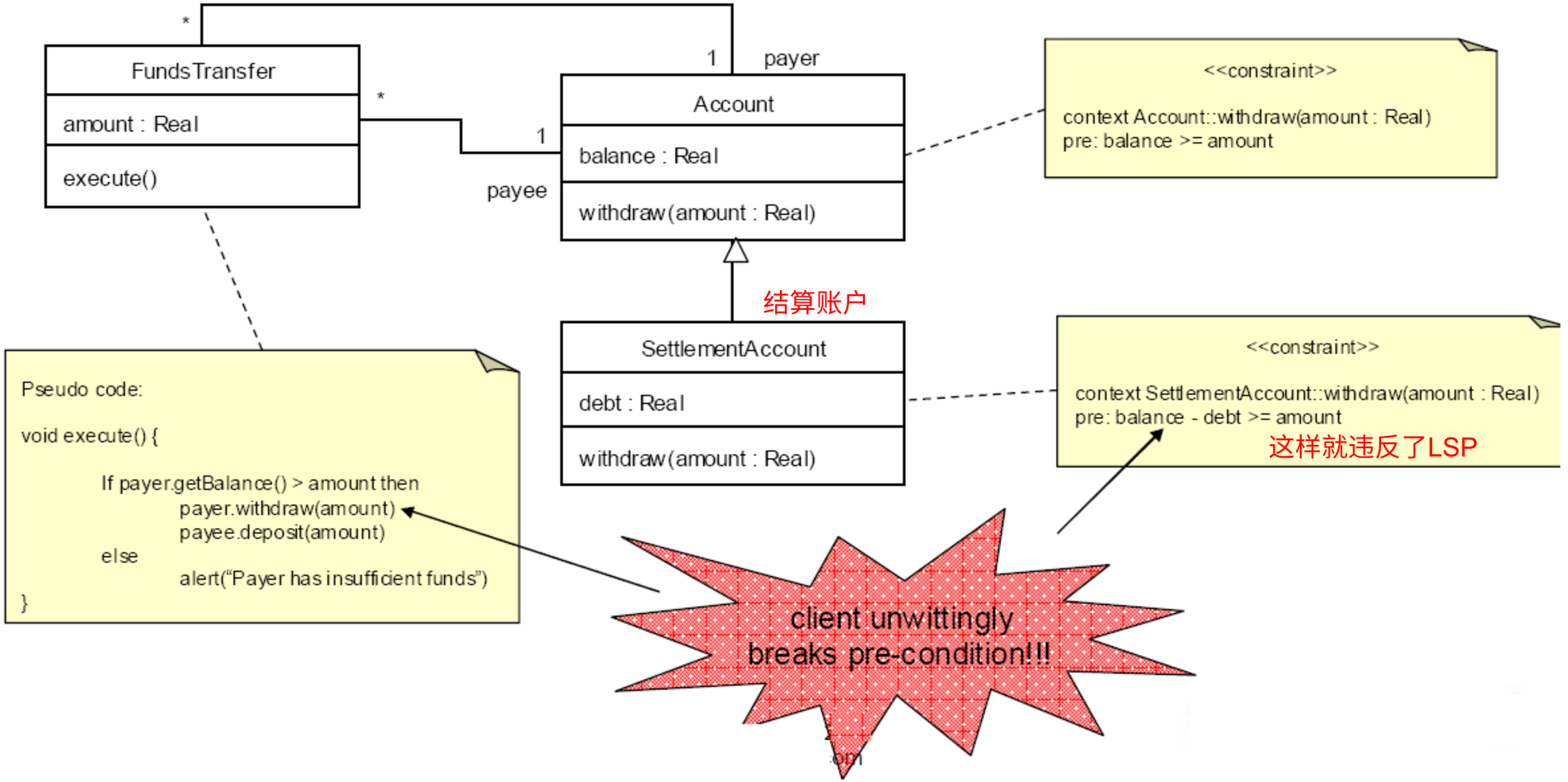
“All derived classes must be substituteable for their base class”

— Barbara Liskov, 1988

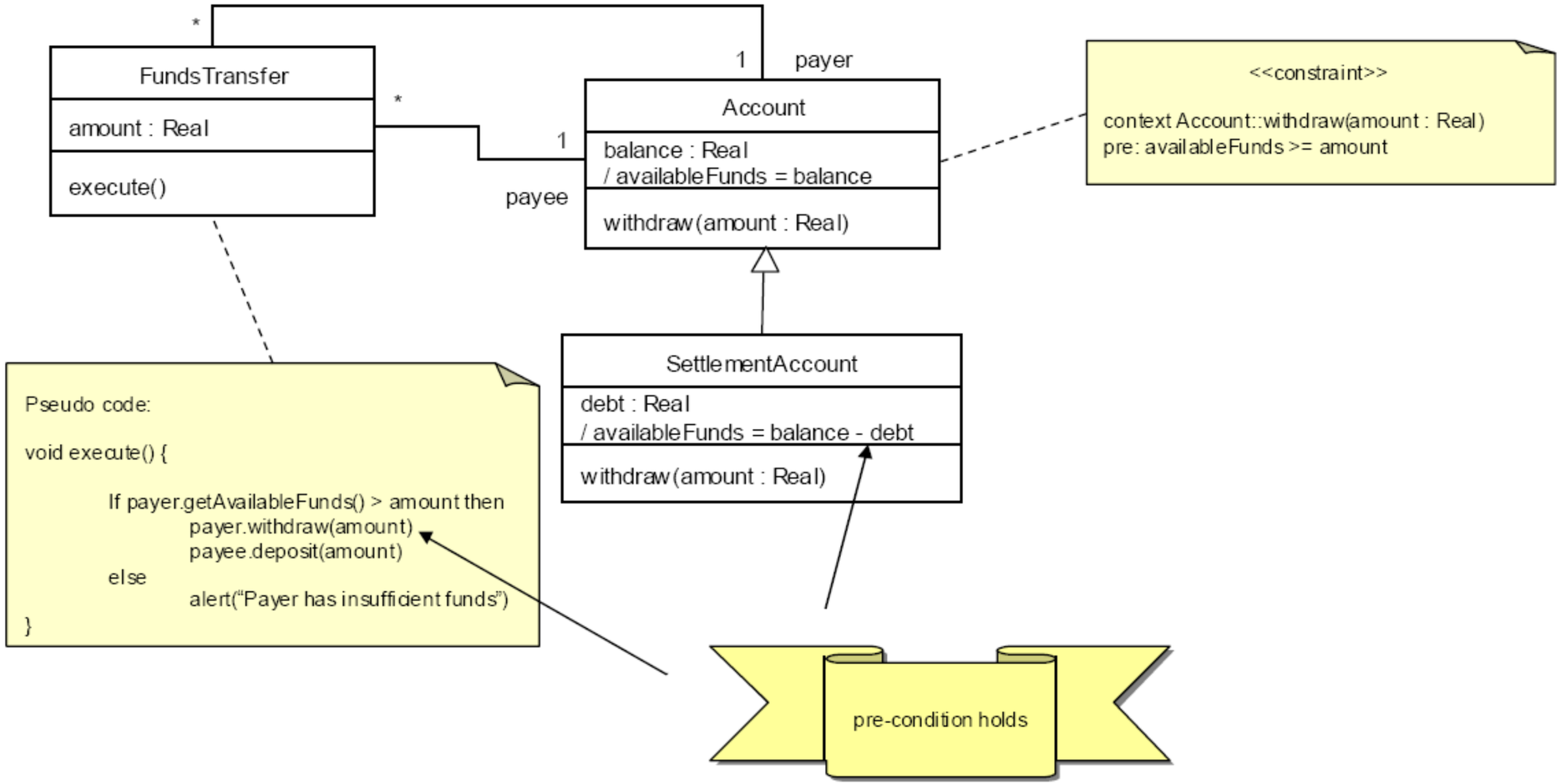
“Functions that use pointers or references to base classes must be able to use objects of derived classes without knowing it.”

— R. Martin, 1996

问题案例


*
FundsTransfer
amount : Real
execute()
*
1
payer
Account
balance : Real
withdraw(amount : Real)
1
payee
<<constraint>>
context Account::withdraw(amount : Real)
pre: balance >= amount
结算账户
SettlementAccount
debt : Real
withdraw(amount : Real)
<<constraint>>
context SettlementAccount::withdraw(amount : Real)
pre: balance - debt >= amount
这样就违反了LSP
Pseudo code:
void execute() {
If payer.getBalance() > amount then
payer.withdraw(amount)
payee.deposit(amount)
else
alert("Payer has insufficient funds")
}
client unwittingly
breaks pre-condition!!!

解决方案


*
1
payer
FundsTransfer
amount : Real
execute()
*
1
payee
Account
balance : Real
/ availableFunds = balance
withdraw(amount : Real)
<<constraint>>
context Account::withdraw(amount : Real)
pre: availableFunds >= amount
SettlementAccount
debt : Real
/ availableFunds = balance - debt
withdraw(amount : Real)
Pseudo code:
void execute() {
If payer.getAvailableFunds() > amount then
payer.withdraw(amount)
payee.deposit(amount)
else
alert("Payer has insufficient funds")
}
pre-condition holds

问题案例 Is a Square a Rectangle?

- Rect r = new Rect();
- setWidth = 4;
- setHeight=5;
- assert(20 == getArea());
- class Square extends Rect{
- // Square invariant, height = width
- setWidth(x) {setHeight()=x}
- setHeight(x) {setWidth(x)}
- } // violate LSP?

问题案例 Penguin is a bird?

- class Bird { // has beak, wings,...
- public: virtual void fly(); // Bird can fly
- };

- class Parrot : public Bird { // Parrot is a bird
- public: virtual void mimic(); // Can Repeat words...
- };
- class Penguin : public Bird {
- public: void fly() {
- error (“Penguins don’t fly!”); }
- };

Penguins Fail to Fly!

- void PlayWithBird (Bird abird) {
- abird.fly(); // OK if Parrot.
- // if bird happens to be Penguin...OOOPS!!
- }

Does not model: “Penguins can’t fly”
It models “Penguins may fly, but if they try it is error”
Run-time error if attempt to fly → not desirable
Think about Substitutability - Fails LSP

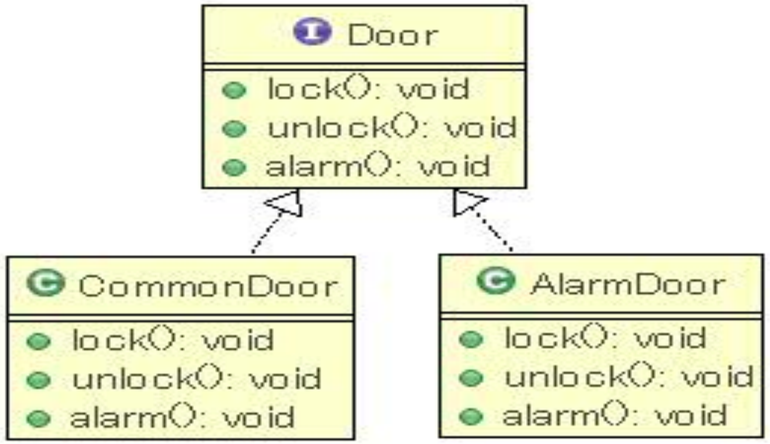
LSP Summary

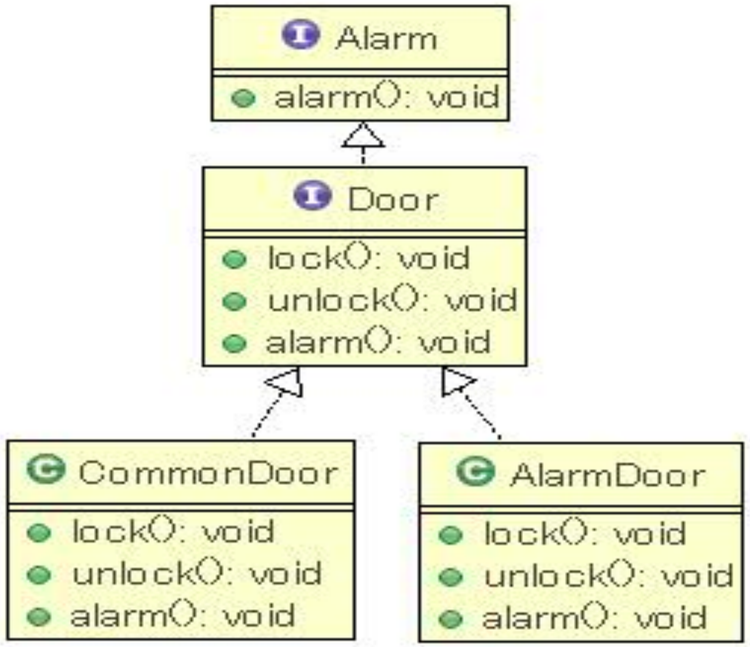
- LSP is about Semantics and Replacement
  - Understand before you design
    - The meaning and purpose of every method and class must be clearly documented
    - Lack of user understanding will induce de facto violations of LSP
  - Replaceability is crucial
    - Whenever any class is referenced by any code in any system,
    - any future or existing subclasses of that class must be 100% replaceable

LSP Summary

“When redefining a method in a derivate class, you may only replace its precondition by a weaker one, and its postcondition by a stronger one”
— B. Meyer, 1988

- Design by Contract
  - Advertised Behavior of an object:
    - advertised Requirements (Preconditions)
    - advertised Promises (Postconditions)
- Derived class services should require no more and promise no less


Door
lock(): void
unlock(): void
alarm(): void
CommonDoor
lock(): void
unlock(): void
alarm(): void
AlarmDoor
lock(): void
unlock(): void
alarm(): void


Alarm
alarm(): void
Door
lock(): void
unlock(): void
alarm(): void
CommonDoor
lock(): void
unlock(): void
alarm(): void
AlarmDoor
lock(): void
unlock(): void
alarm(): void

课堂练习

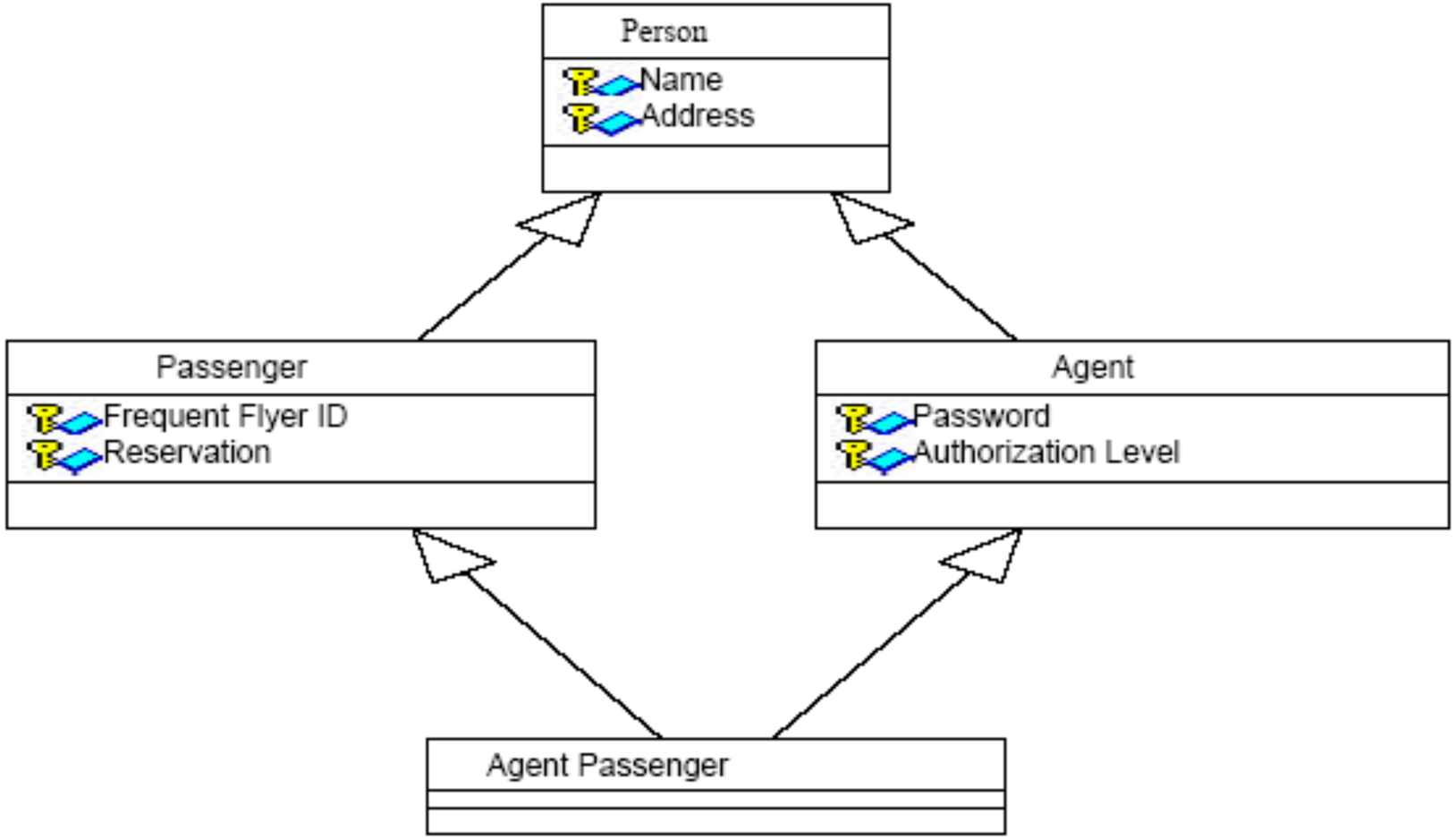
Principle 8 : Favor Composition Over Inheritance

- Favor Composition Over Inheritance
- Use inherit for polymorphism
- Use delegate not inherit to reuse code!

Coad's Rules of Using Inheritance

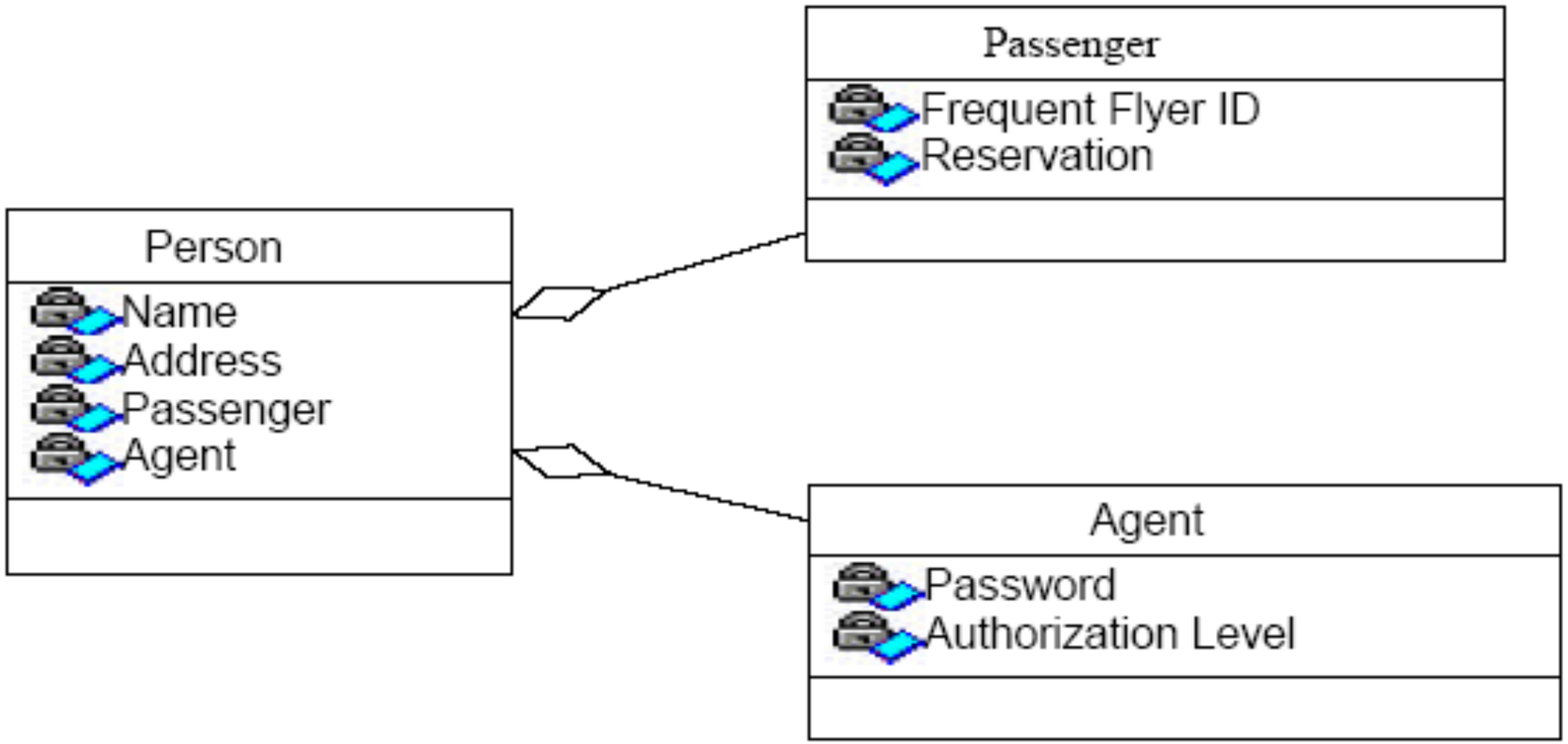
- Use inheritance only when all of the following criteria are satisfied:
  - A subclass expresses "is a special kind of" and not "is a role played by a"
  - An instance of a subclass never needs to become an object of another class
  - A subclass extends, rather than overrides or nullifies, the responsibilities of its superclass
  - A subclass does not extend the capabilities of what is merely an utility class

Inheritance/Composition Example 1

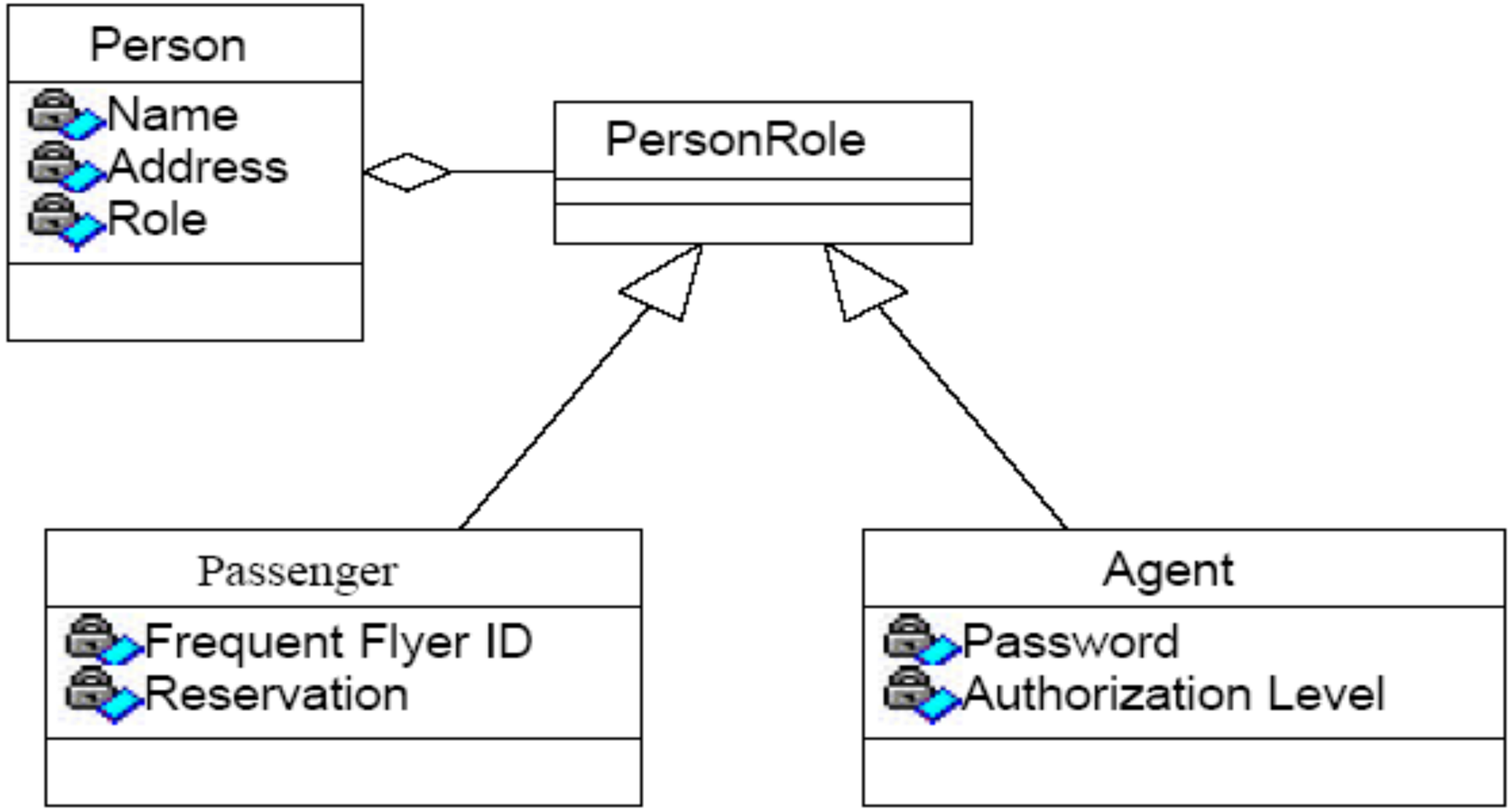


Inheritance/Composition Example 1 (Continued)

Composition to the rescue!



Inheritance/Composition Example 2



- class Object {
- public: virtual void update() {};
  - virtual void draw() {};
  - virtual void collide(Object objects[]) {};
- };

- class Visible : public Object {
  - public: virtual void draw() {
  - /* draw model at position of this object */ };
  - private: Model* model;
  - };

- class Solid : public Object {
  - public: virtual void collide(Object objects[]) {
  - /* check and react to collisions with objects */ };
- };

- class Movable : public Object {
- public: virtual void update() {
- /* update position */ };
- };

-

Outline

- 面向对象中的模块与耦合
- 访问耦合
- 继承耦合
- 内聚
- 耦合和内聚的度量

衡量标准	内聚低的例子	内聚高的例子

方法和属性是否一致	小计每一购物项金额的方法放在 Sales 类中
	class Sales{
	HashMap<Integer, SalesLineItem> map;
	getSubtotal(int CommodityID){
	1）根据 CommodityID 找到 Commodity 的价格
	2）根据 CommodityID 找到 SalesLineItem，再找到商品购买的数量
	3）计算小计
	}
	}
		小计每一购物项金额的方法放在 SalesLineItem 中。计算总额的类在 Sales 类中。
		class Sales{
		HashMap<Integer, SalesLineItem> map;
		getTotal(){
		遍历 map 中的 item
		total = item.getSubtotal();
		}
		}
		class SalesLineItem{
		Commodity commodity;
		Int quantity;
		getSubtotal();
		}

衡量标准	内聚低的例子	内聚高的例子

属性之间是否体现一个职责	学号、姓名、成绩、课程编号、课程名在一个类里面
	class SCORE{
	int studentID;
	String name;
	int score;
	int courseID;
	String courseName;
	}
		学号、姓名在学生类中；课程编号、课程名在课程类中；学生、课程、成绩在成绩类中
		class Student{
		int studentID;
		String name;
		}
		class Course{
		int courseID;
		String courseName;
		}
		class SCORE{
		Student student;
		Course course;
		int score;
		}

属性之间可否抽象	生产年份、生产月份、生产日期、进货年份、进货月份、进货日期在一个类里面
	`class Product{`
	`  int yearOfProduction;`
	`  int monthOfProduction;`
	`  int dayOfProduction;`
	`  int yearOfImport;`
	`  int monthOfImport;`
	`  int dayOfImport;`
	`}`
		抽象出日期类包含年、月、日三个属性。类里面只有日期类的生产日期和进货日期两个变量
		`class Date{`
		`  int year;`
		`  int month;`
		`  int day;`
		`}`
		`class Product{`
		`  Date productionDate;`
		`  Date importDate;`
		`}`

Cohesion of methods

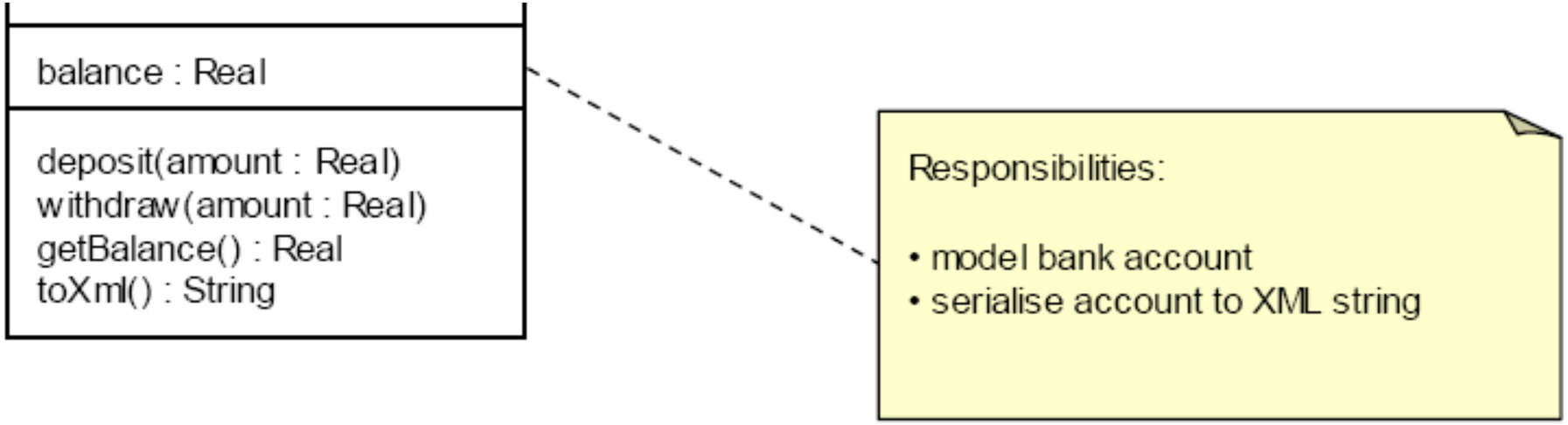
- Methods of a Class are Common coupling
- All methods serve One Responsibility
  - Informational Cohesion
  - Relative functions (functional Cohesion)
  - Principle 9: Single Responsibility Principle

Single Responsibility Principle (SRP)

- “A class should have only one reason to change”
- — Robert Martin

- Related to and derived from cohesion, i.e. that elements in a module should be closely related in their function

- Responsibility of a class to perform a certain function also a reason for the class to change

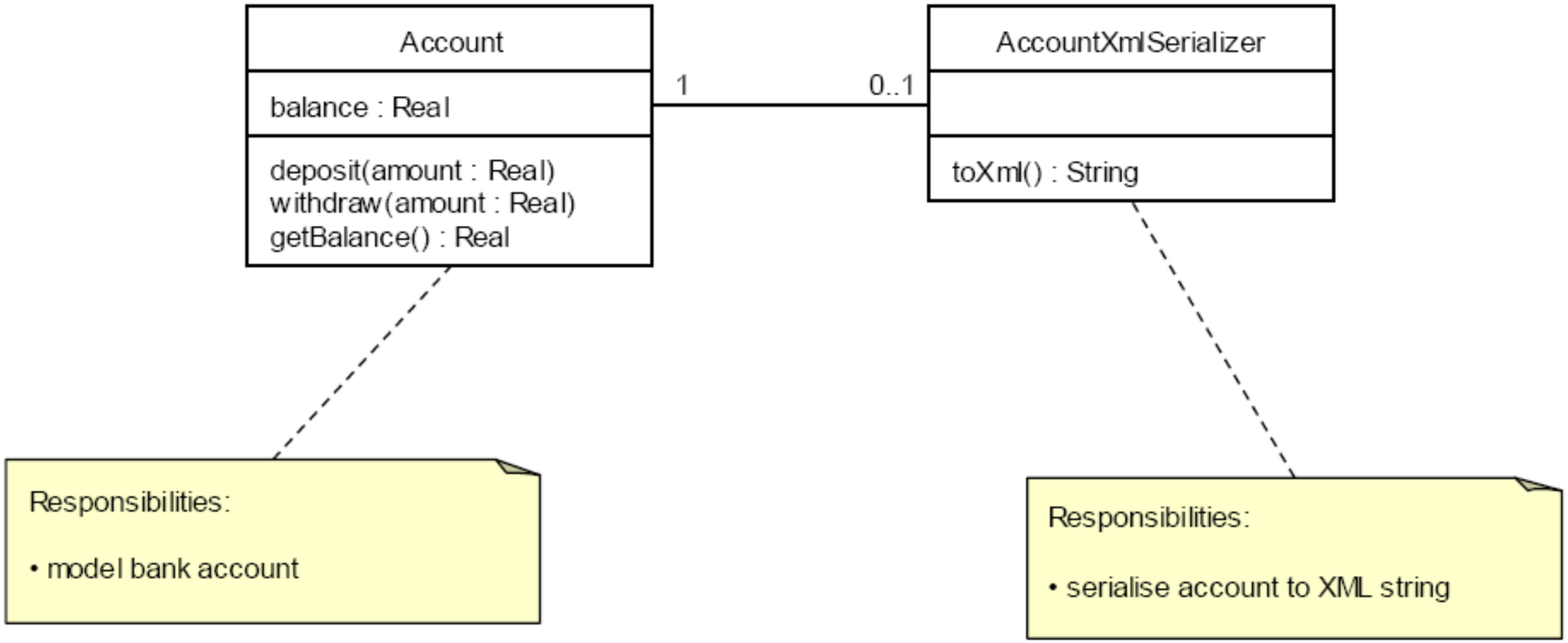


Two reasons why this class might need to change

- changes to domain logic

SRP Example

问题案例

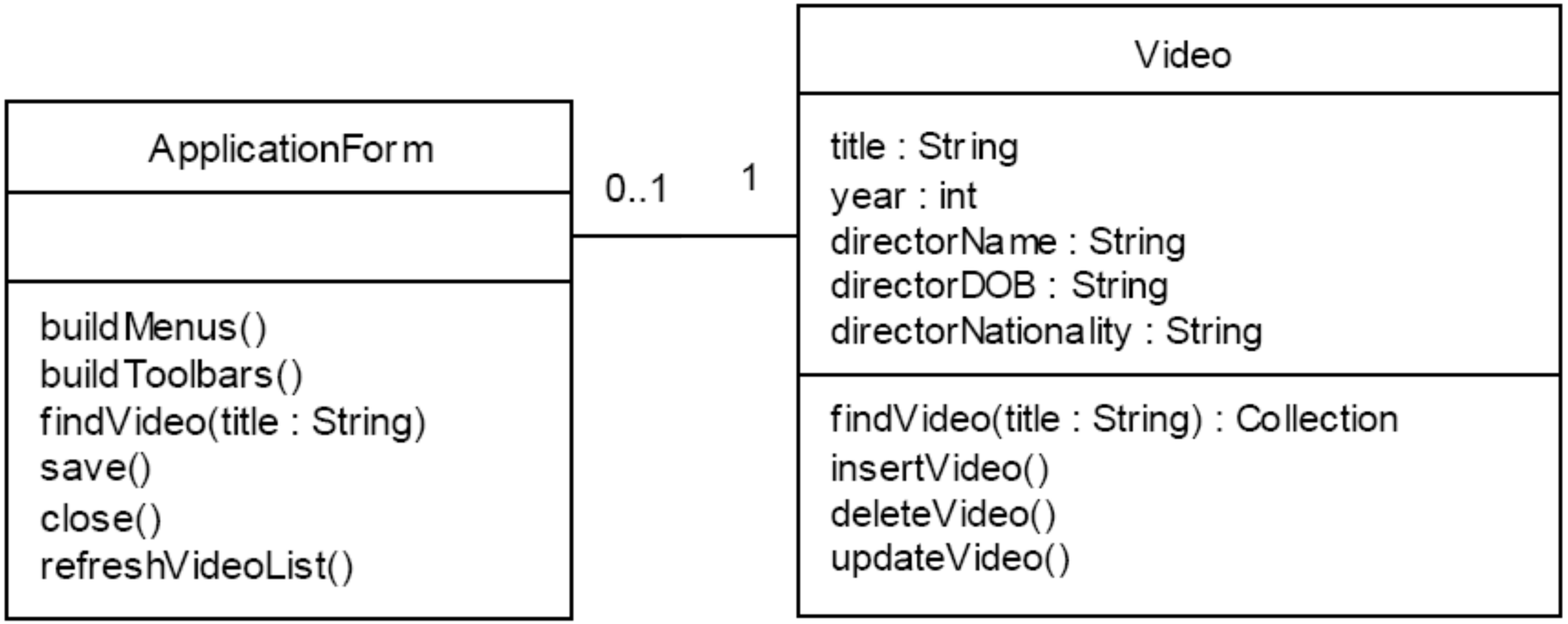


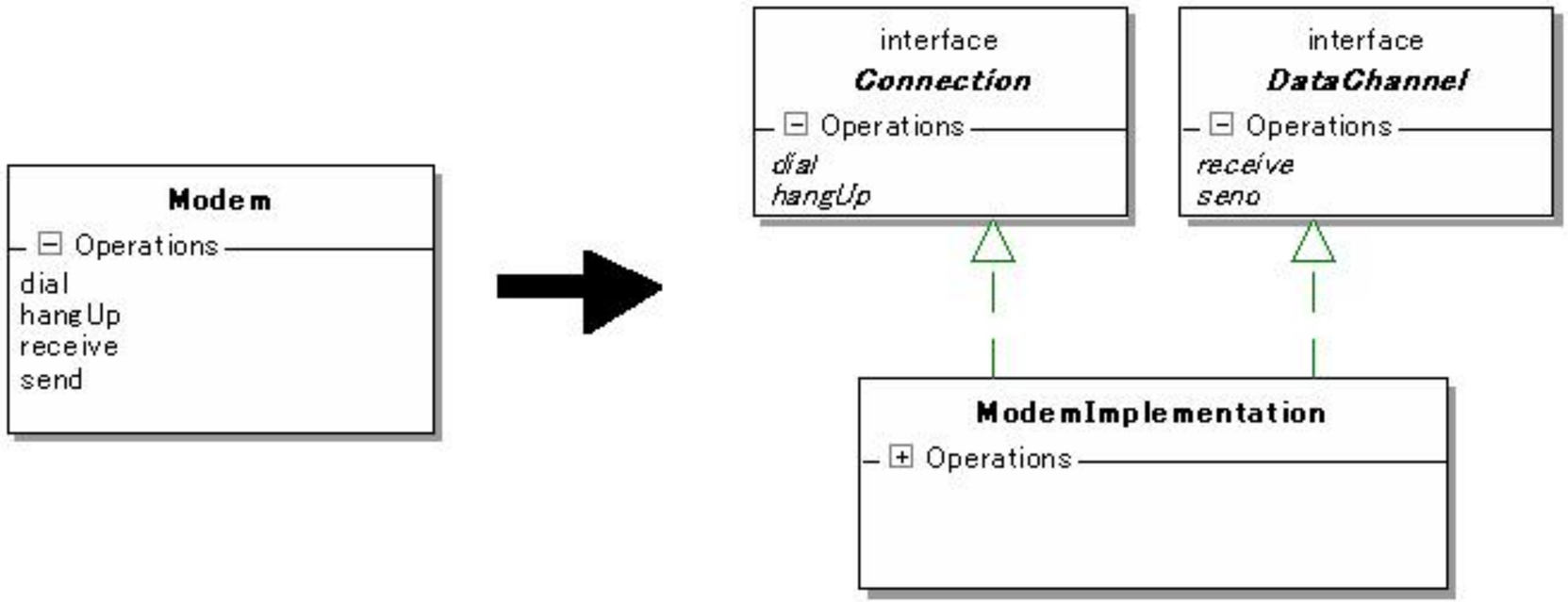
SRP Example

结局方案

SRP Summary

- Class should have only one reason to change
  - Cohesion of its functions/responsibilities
- Several responsibilities
  - mean several reasons for changes → more frequent changes
- Sounds simple enough
  - Not so easy in real life
  - Tradeoffs with complexity, repetition, opacity


ApplicationForm
buildMenus()
buildToolbars()
findVideo(title : String)
save()
close()
refreshVideoList()
0..1
1
Video
title : String
year : int
directorName : String
directorDOB : String
directorNationality : String
findVideo(title : String) : Collection
insertVideo()
deleteVideo()
updateVideo()


Modem
Operations
dial
hangUp
receive
send
interface
Connection
Operations
dial
hangUp
interface
DataChannel
Operations
receive
send
ModemImplementation
Operations

课堂练习

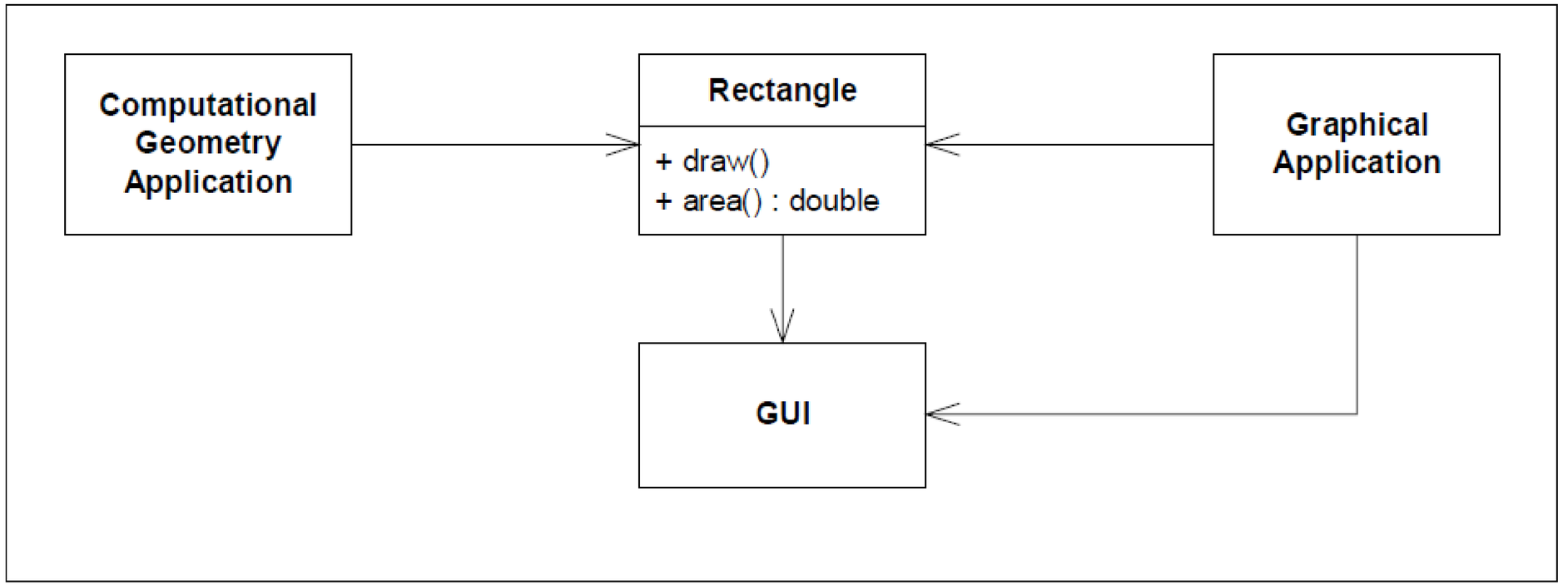


Figure 9-1
More than one responsibility

课堂练习

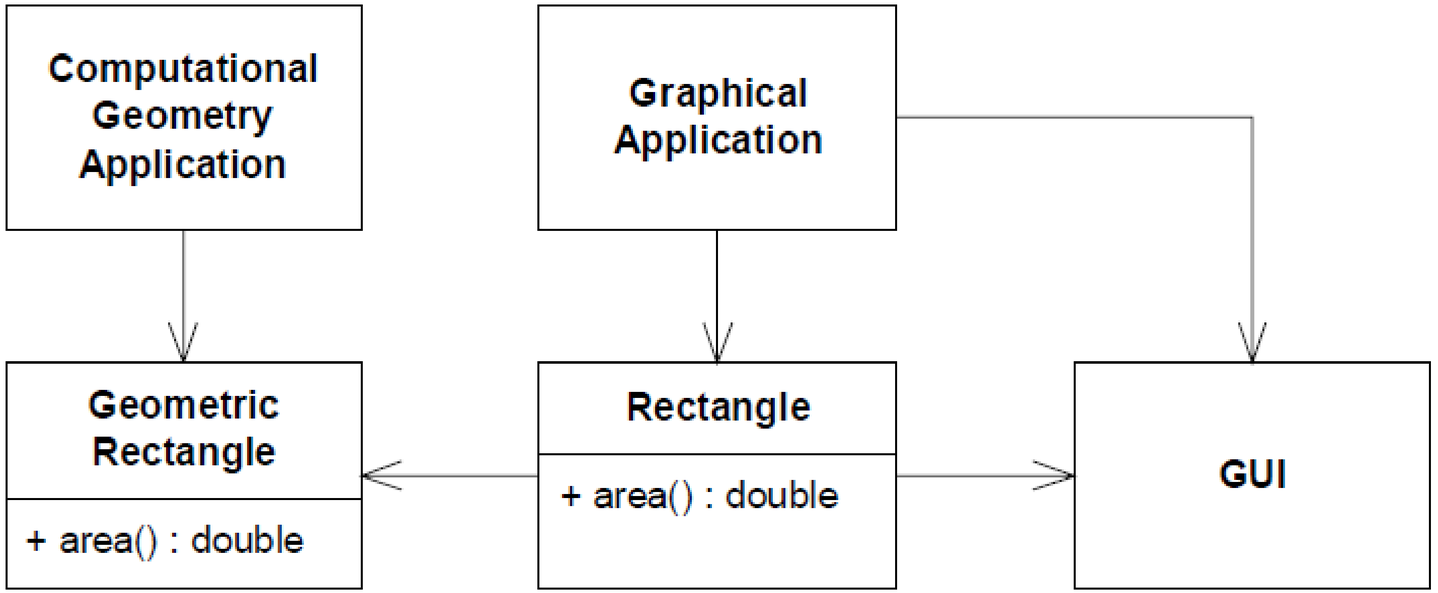


Figure 9-2
Separated Responsibilities

解决方案

Outline

- 面向对象中的模块与耦合
- 访问耦合
- 继承耦合
- 内聚
- 耦合和内聚的度量

Coupling Metrics between classes

- Coupling between object classes (CBO)
- A count of the number of other classes:
  - which access a method or variable in this class, or
  - contain a method or variable accessed by this class
  - Not including Inheritance
- Want to keep this low

Coupling Metrics between classes

- Data abstraction coupling (DAC)
- The number of attribute having an ADT type dependent on the definitions of other classes
- Want to keep this low

Coupling Metrics between classes

- Ce and Ca (efferent and afferent coupling)
  - Ca:
    - The number of classes outside this category that depend upon classes within this category.
  - Ce:
    - The number of classes inside this category that depend upon classes outside this category
- Want to keep these low

Coupling Metrics between classes

- Depth of the Inheritance tree (DIT)
  - the maximum length from the node to the root of the tree
  - as DIT grows, it becomes difficult to predict behavior of a class because of the high degree of inheritance
  - Positively, large DIT values imply that many methods may be reused

Coupling Metrics between classes

- Number of children (NOC)
  - count of the subclasses immediately subordinate to a class
  - as NOC grows, reuse increases
  - as NOC grows, abstraction can become diluted
  - increase in NOC means the amount of testing will increase

Measure class cohesion

- Lack of cohesion in methods (LCOM)

"Consider a Class C_1 with n methods M_1, M_2, ..., M_n. Let
{Ij} = set of instance variables used by Method Mj.
There are n such sets $\{I_1\}$, ..., $\{I_n\}$.
Let $P = \{(I_i, I_j) \mid I_i \cap I_j = \emptyset\}$ and $Q = \{(I_i, I_j) \mid I_i \cap I_j \neq \emptyset\}$.
If all n sets $\{I_1\}$, ..., $\{I_n\}$ are $\emptyset$ then let $P = \emptyset$.
$LCOM = |P| - |Q|$. if $|P| > |Q|$
$= 0$ otherwise."

- Want to keep this low
- Many other versions of LCOM have been defined

Measure class cohesion

- If LCOM >=1, then the class should be separated

Let X denote a class, I_X the set of its instance variables of X, and M_X the set of its methods. Consider a simple, undirected graph $G_X(V, E)$ with

$V = M_X$ and $E = \{<m, n> \in V \times V \mid \exists\ i \in I_X$: (m accesses i) $\wedge$ (n accesses i)$\}$.

LCOM(X) is then defined as the number of connected components of G_X ($1 \leq LCOM(X) \leq |M_X|$).

Summary

- Principles from Modularization
  - 1: 《Global Variables Consider Harmful》
  - 2: 《To be Explicit》
  - 3: 《Do not Repeat》
  - 4: 《Programming to Interface(Design by Contract Design by Contract)》

Summary

- 5: 《The Law of Demeter》
- 6: 《Interface Segregation Principle(ISP)》
- 7: 《Liskov Substitution Principle (LSP)》
- 8: 《Favor Composition Over Inheritance》
- 9: 《Single Responsibility Principle》