Chapter 6: Maintainability-Oriented Software Construction Approaches

6.1 Metrics and Construction Principles for Maintainability

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Outline

- **Software Maintenance and Evolution**
- **Metrics of Maintainability**
- **Modular Design and Modularity Principles**
- **OO Design Principles: SOLID**
- **OO Design Principles: GRASP**
- **Summary**

1 Software Maintenance and Evolution

What is Software Maintenance?

- **Software maintenance** in software engineering is the modification of a software product after delivery to correct faults, to improve performance or other attributes.
- In "ISO/IEC 14764:2006 Software Engineering— Software Life Cycle Processes — Maintenance"

Operation & Maintenance Engineer

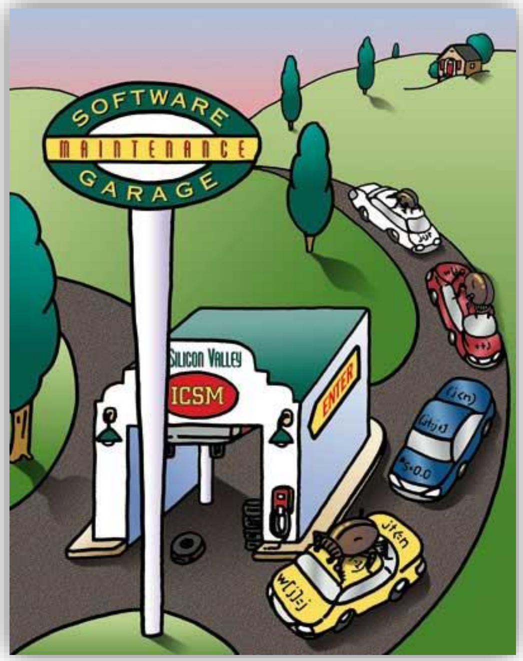
- **Maintenance is one of the most difficult aspects of software production because maintenance incorporates aspects of all other phases**
- **A fault is reported from users and is to be handled by a maintenance engineer.**
- **A maintenance engineer must have superb debugging skills**
  - The fault could lie anywhere within the product, and the original cause of the fault might lie in the by now non-existent specifications or design documents (bug/issue localization).
  - Superb diagnostic skills, testing skills and documentation skills are required (testing, fix, and documenting changes).

After fixing the code

- **More Steps:**
  - **Test that the modification works correctly**: use specially constructed test cases
  - **Check for regression faults(回归性错误)**: use stored test data, and add specially constructed test cases to stored test data for future regression testing
  - **Document all changes**
- **How to minimize regression faults**
  - Consult the detailed documentation and make use of constructed test cases.
- **What usually happens: no enough documentation / test cases;**
- **The operation engineer has to deduce from the source code itself all the information needed to avoid introducing a regression fault.**

Types of software maintenance

- **Corrective maintenance 25% 纠正性维护**
  - Reactive modification of a software product performed after delivery to correct discovered problems;
- **Adaptive maintenance 21% 适应性维护**
  - Modification of a software product performed after delivery to keep a software product usable in a changed or changing environment;
- **Perfective maintenance 50% 完善性维护**
  - Enhancement of a software product after delivery to improve performance or maintainability;
- **Preventive maintenance 4% 预防性维护**
  - Modification of a software product after delivery to detect and correct latent faults in the software product before they become effective faults.

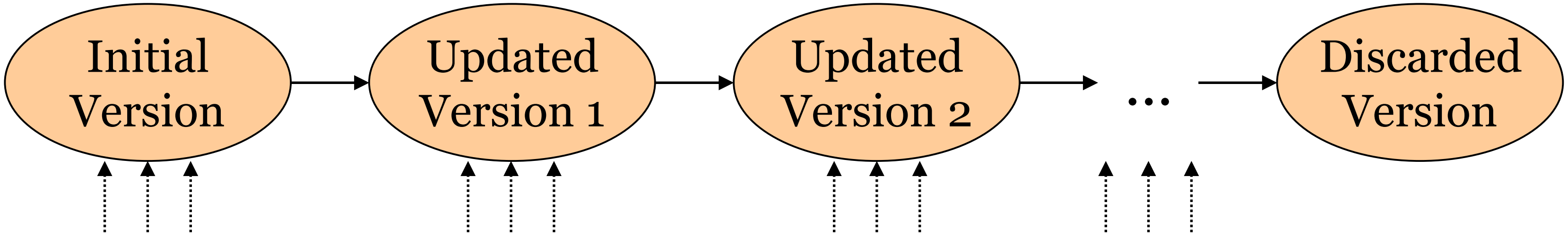


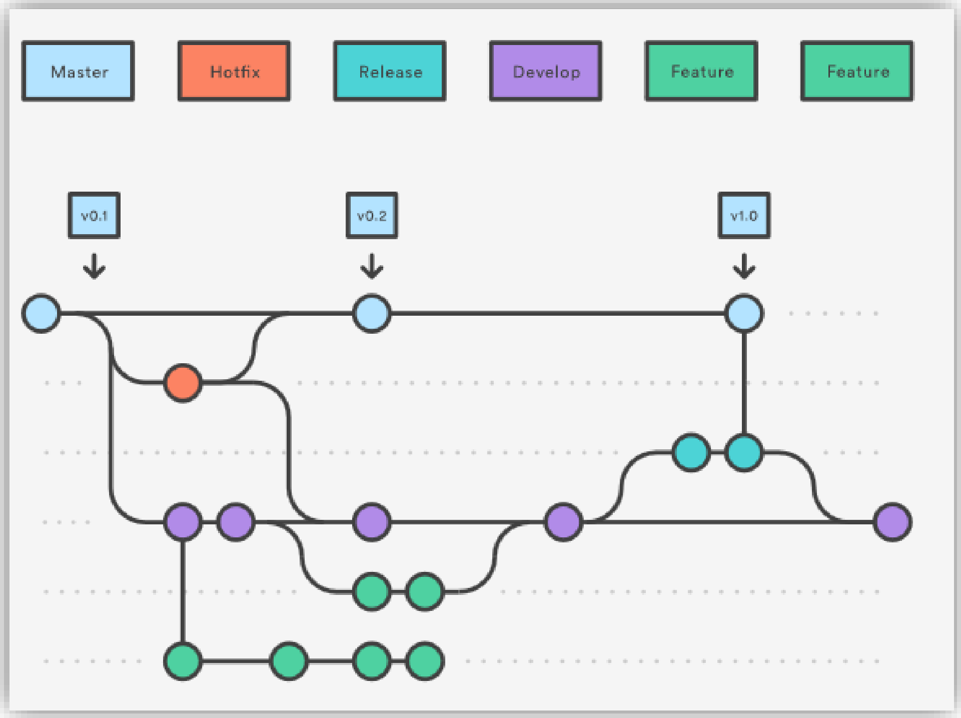
Software Evolution

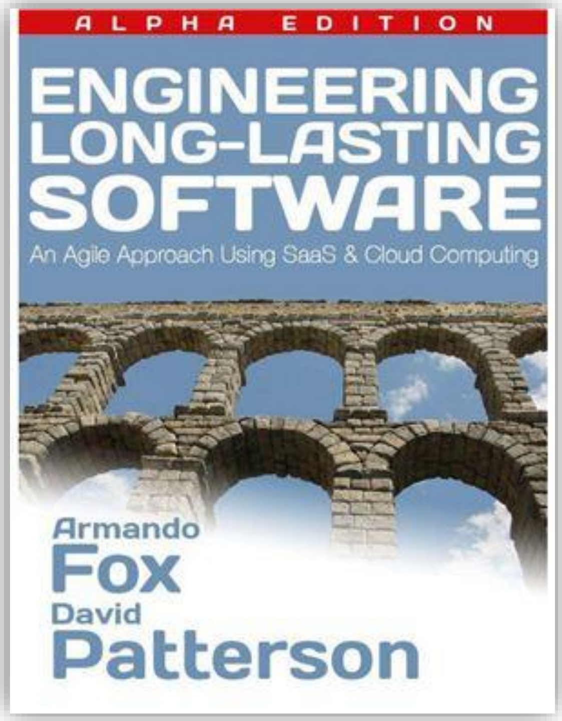
- **Software evolution is a term used in software maintenance, referring to the process of developing software initially, then repeatedly updating it for various reasons.**
- **Over 90% of the costs of a typical system arise in the maintenance phase, and that any successful piece of software will inevitably be maintained.**

Software Evolution

- **Multiple versions in the life of a software: From 1 to *n***







ALPHA EDITION

ENGINEERING LONG-LASTING SOFTWARE

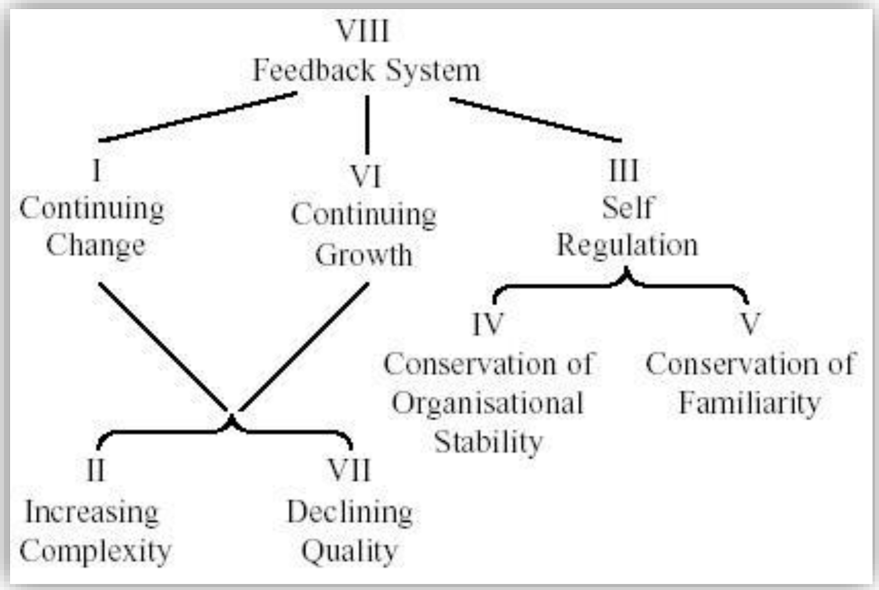
An Agile Approach Using SaaS & Cloud Computing

Armando Fox

David Patterson

Lehman's Laws on Software Evolution

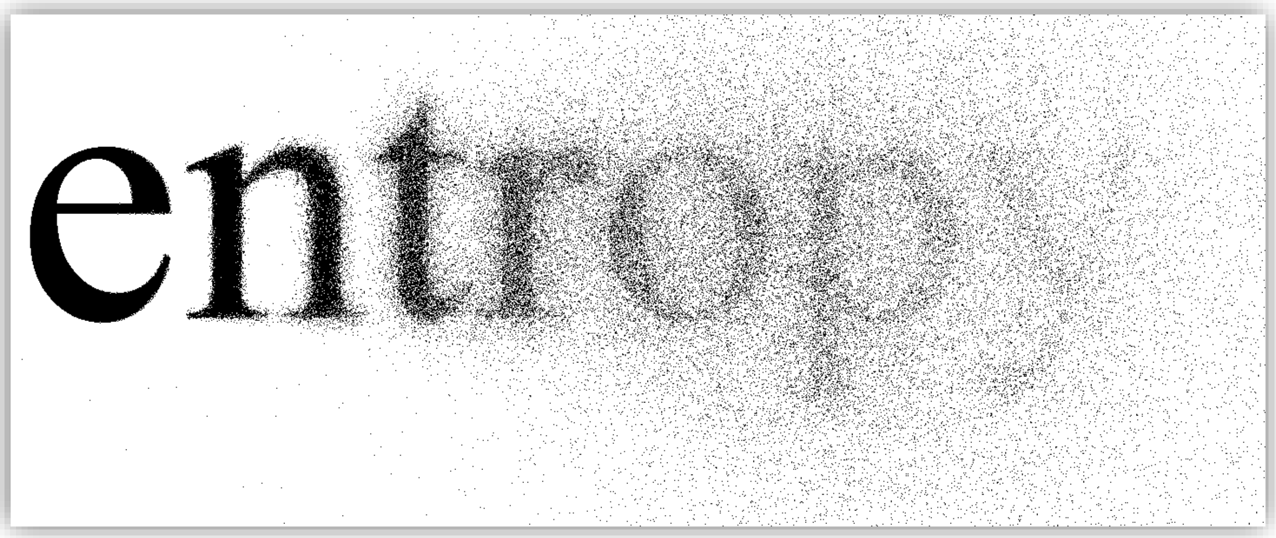
- **An *E-program* is written to perform some real-world activity; how it should behave is strongly linked to the environment in which it runs, and such a program needs to adapt to varying requirements and circumstances in that environment**
- **Eight laws were formulated:**
  - Feedback System
  - Continuing Change
  - Continuing Growth
  - Declining Quality
  - Increasing Complexity
  - Self Regulation
    - Conservation of Organizational Stability
    - Conservation of Familiarity



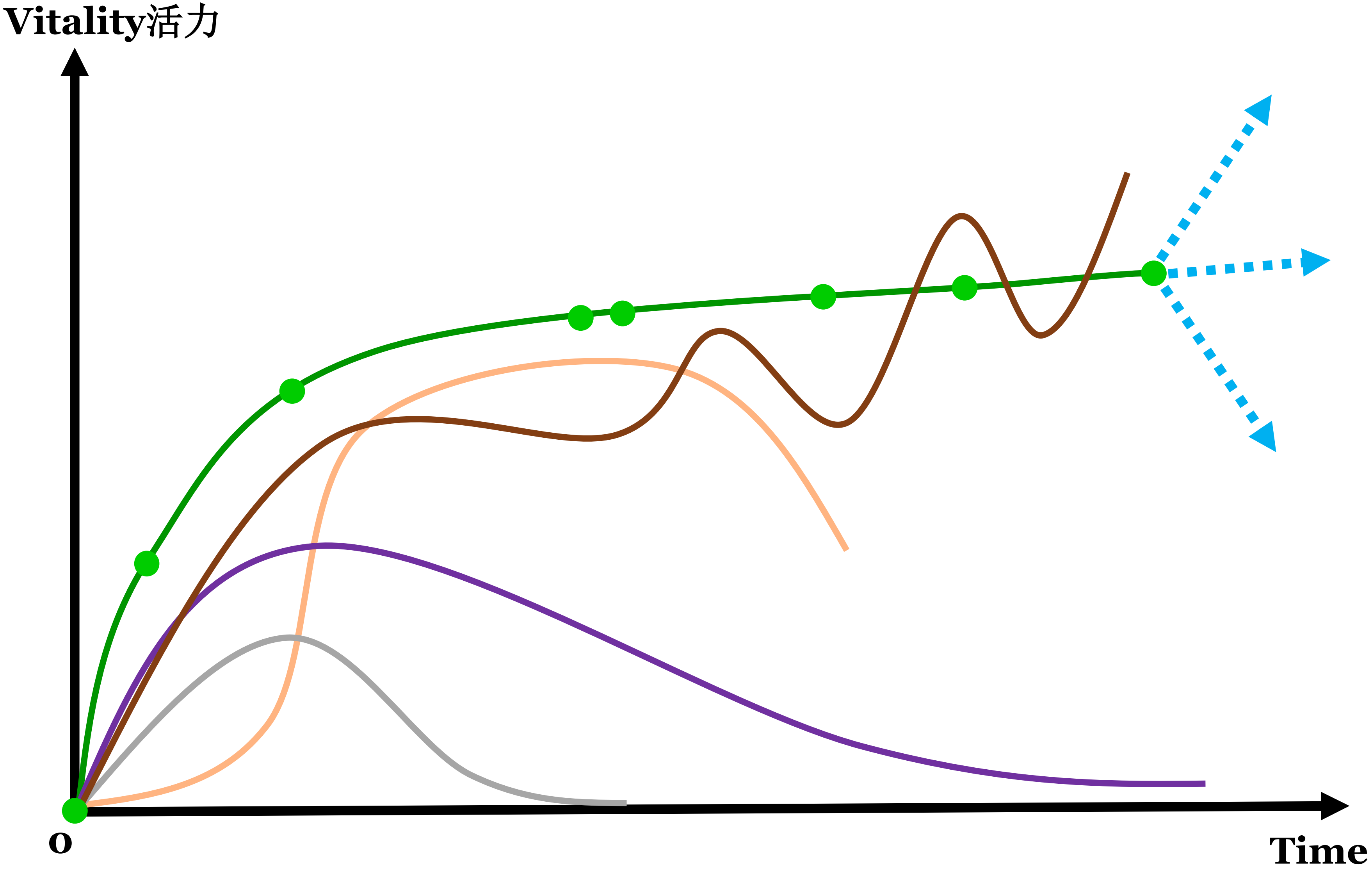
Software Entropy熵

- **As a system is modified, its disorder, or entropy, tends to increase.**
- **This is known as software entropy.**

（entropy熵：物理意义是系统混乱程度的度量）

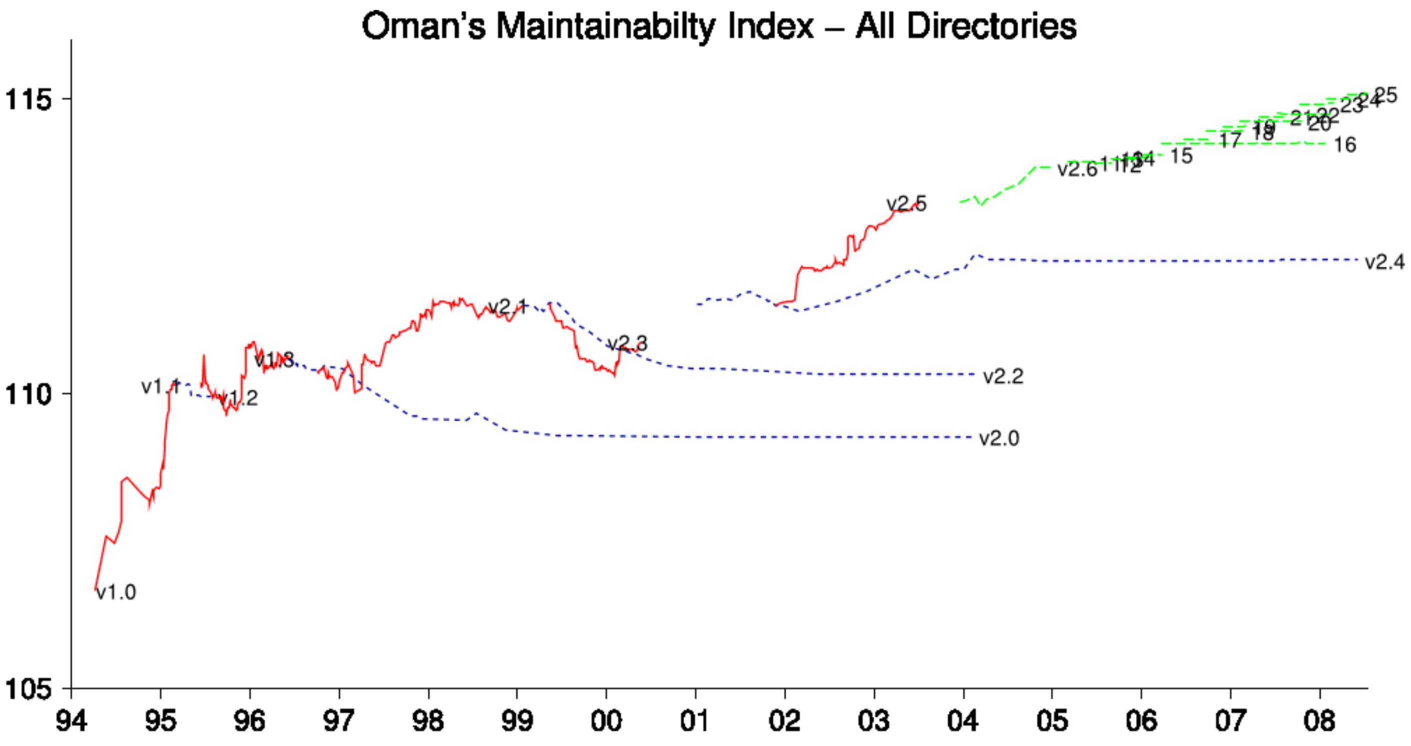


Life patterns of software



Objective of software maintenance and evolution

- **Objective of software maintenance and evolution: To improve the fitness / adaptability of software, and keep its vitality, i.e., “long-lasting software (low entropy software)”**
- **An example of Linux Kernel’s evolution: its Maintainability Index.**



Maintenance is not just the task of op engineers…

- **Maintenance is not just the task of maintenance and operation engineers, but also a potential task of software designers and developers. 维护不仅是维护人员的责任，也是设计和开发者的责任**
- **For them, it is mandatory to consider future potential changes/extensions of the software during the design and construction phases;设计和开发者需要考虑软件未来的变化和扩展**
- **So that flexible and extensible design/constructions are comprehensively considered, in other words, “easy to change / extension”.**
- **This is what’s called “maintainability”, “extensibility” and “flexibility” of software construction.**

Examples of maintainability-oriented construction

- **Modular design and implementation**
  - Low coupling and high cohesion
- **OO design principles**
  - SOLID
  - GRASP
- **OO design patterns**
  - Factory method pattern, Builder pattern
  - Bridge pattern, Proxy pattern
  - Memento pattern, State pattern
- **State-based construction (Automata-based programming)**
- **Table-driven construction**
- **Grammar-based construction**

These are what to be studied in this Chapter

2 Metrics of Maintainability

Many names of maintainability

Ready for Change
Ready for Extension

- **Maintainability** – "The ease with which a software system or component can be modified to correct faults, improve performance, or other attributes, or adapt to a changed environment".
- **Extensibility** – Software design/implementation takes future growth into consideration and is seen as a systemic measure of the ability to extend a system and the level of effort required to implement the extension.
- **Flexibility** – The ability of software to change easily in response to user requirements, external technical and social environments, etc.
- **Adaptability** – The ability of an interactive system (adaptive system) that can adapt its behavior to individual users based on information acquired about its user(s) and its environment.

Many names of maintainability

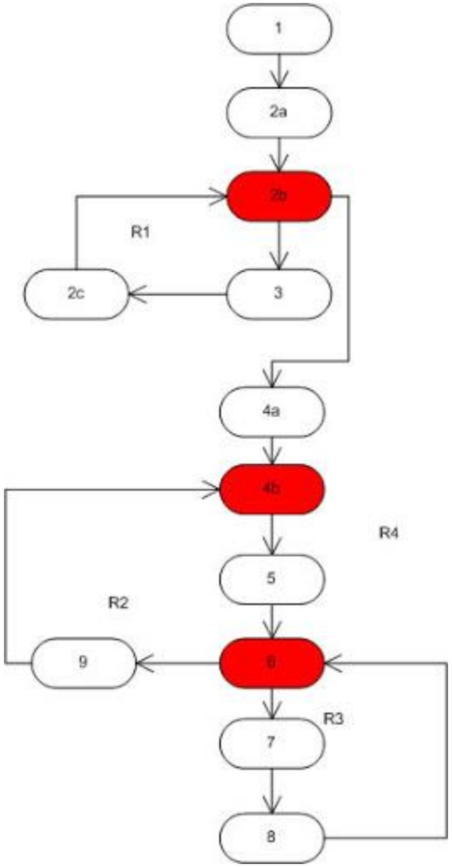
- **Manageability—How efficiently and easily a software system can be monitored and maintained to keep the system performing, secure, and running smoothly.**
- **Supportability—How effectively a software can be kept running after deployment, based on resources that include quality documentation, diagnostic information, and knowledgeable and available technical staff.**

Questions about maintainability

- **Structural and design simplicity: how easy is it to change things?**
- **Are things tightly or loosely coupled (i.e., separation of concerns)?**
- **Are all elements in a package/module cohesive and their responsibilities clear and closely related?**
- **Does it have overly deep inheritance hierarchies or does it favor composition over inheritance?**
- **How many independent paths of execution are there in the method definitions (i.e., cyclomatic complexity)?**
- **How much code duplication exists?**

Some common-used maintainability metrics

- **Cyclomatic Complexity** - Measures the structural complexity of the code.
  - It is created by calculating the number of different code paths in the flow of the program.
  - A program that has complex control flow will require more tests to achieve good code coverage and will be less maintainable.
  - CC = E-N+2, CC=P+1, CC=number of areas
- **Lines of Code** - Indicates the approximate number of lines in the code.
  - A very high count might indicate that a type or method is trying to do too much work and should be split up.
  - It might also indicate that the type or method might be hard to maintain.



Some common-used maintainability metrics

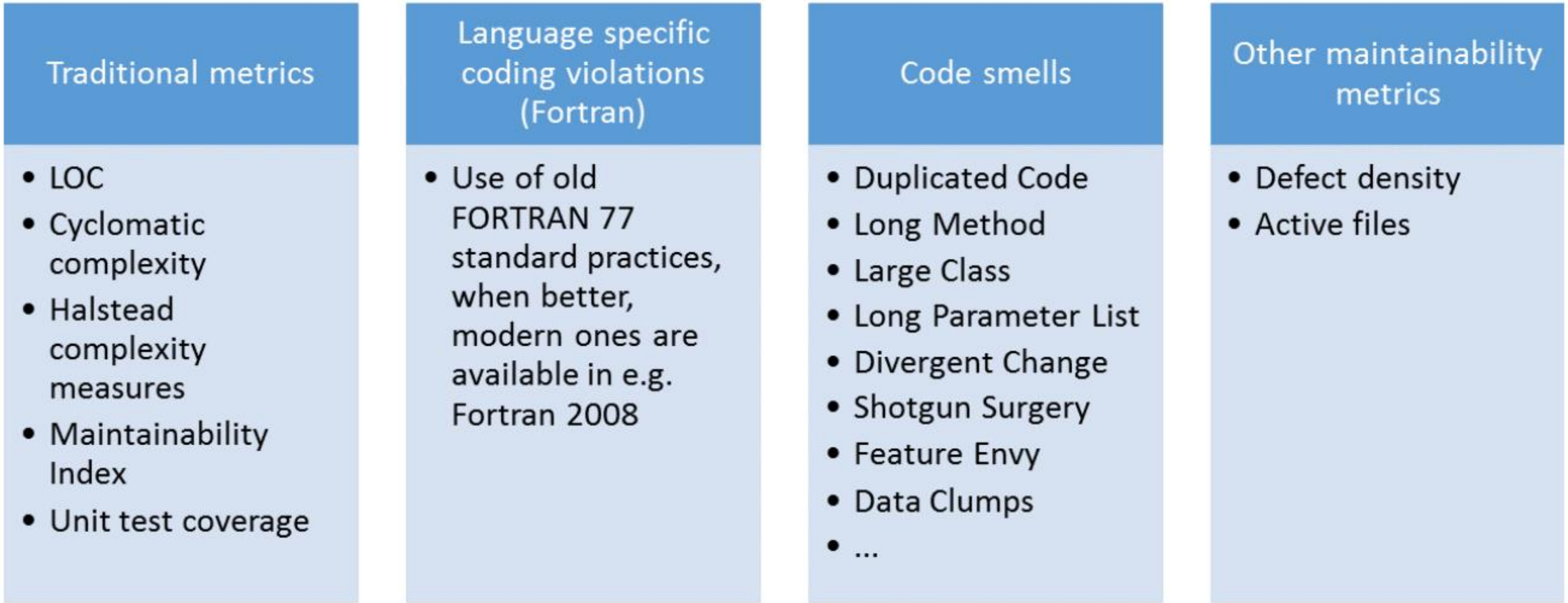
- **Halstead Volume:** a composite metric based on the number of (distinct) operators and operands in source code. 运算符和操作数的数目
- **Maintainability Index (MI)** - Calculates an index value between 0 and 100 that represents the relative ease of maintaining the code. A high value means better maintainability. It is calculated based on:
  - Halstead Volume (HV)
  - Cyclomatic Complexity (CC)
  - The average number of lines of code per module (LOC)
  - The percentage of comment lines per module (COM).

$$171 - 5.2 ln(\mathrm{HV}) - 0.23\mathrm{CC} - 16.2 ln(\mathrm{LOC}) + 50.0 sin\sqrt{2.46 * \mathrm{COM}}$$

Some common-used maintainability metrics

- **Depth of Inheritance** - Indicates the number of class definitions that extend to the root of the class hierarchy. **The deeper the hierarchy the more difficult it might be to understand** where particular methods and fields are defined or/and redefined.
- **Class Coupling** - Measures the coupling to unique classes through parameters, local variables, return types, method calls, generic or template instantiations, base classes, interface implementations, fields defined on external types, and attribute decoration.
  - **Good software design dictates that types and methods should have high cohesion and low coupling.**
  - High coupling indicates a design that is difficult to reuse and maintain because of its many interdependencies on other types.
- **Unit test coverage -** indicates what part of the code base is covered by automated unit tests. (to be studied in Chapter 7)

Many other maintainability metrics



Traditional metrics

- LOC
- Cyclomatic complexity
- Halstead complexity measures
- Maintainability Index
- Unit test coverage

Language specific coding violations (Fortran)

- Use of old FORTRAN 77 standard practices, when better, modern ones are available in e.g. Fortran 2008

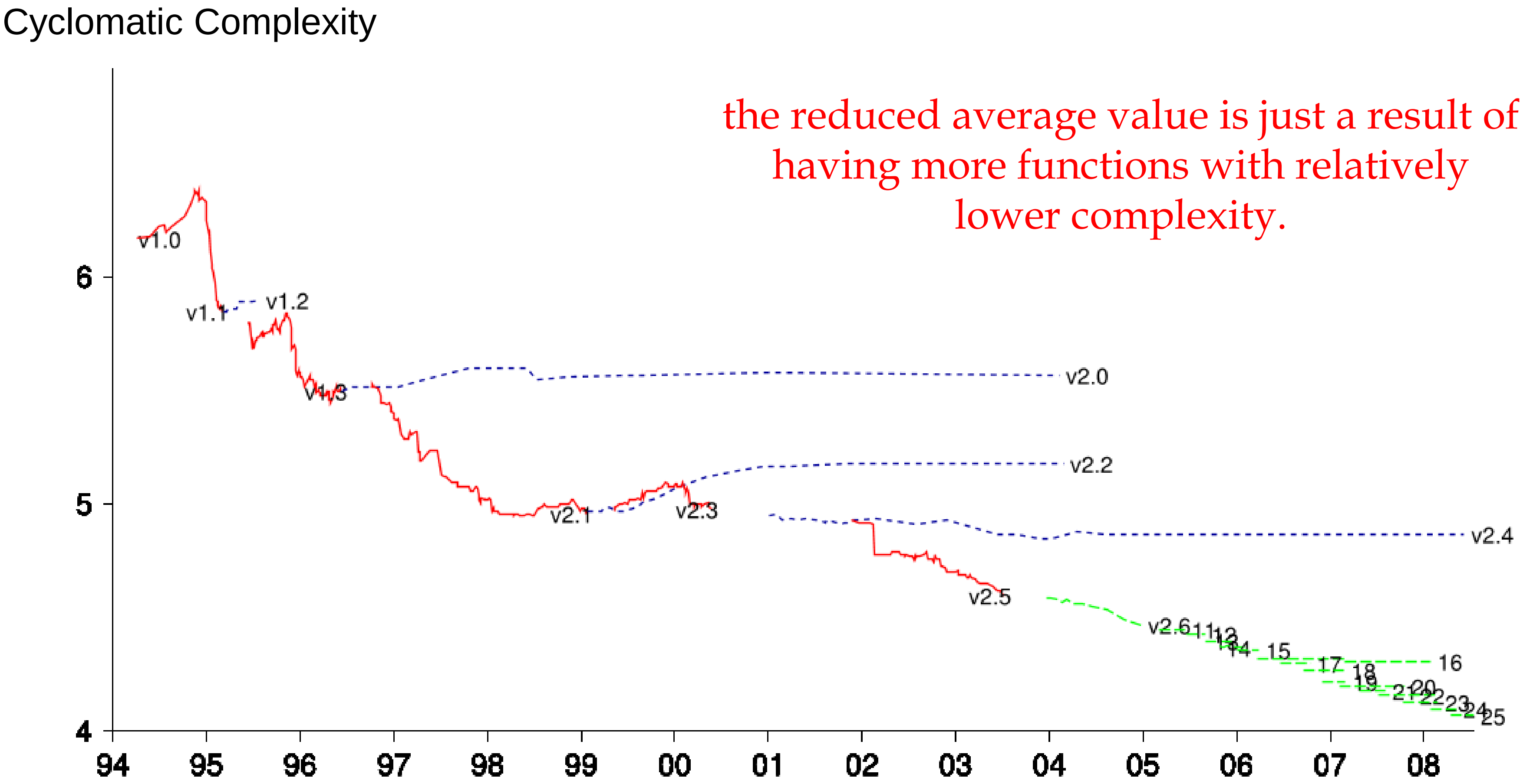
Code smells

- Duplicated Code
- Long Method
- Large Class
- Long Parameter List
- Divergent Change
- Shotgun Surgery
- Feature Envy
- Data Clumps
- …

Other maintainability metrics

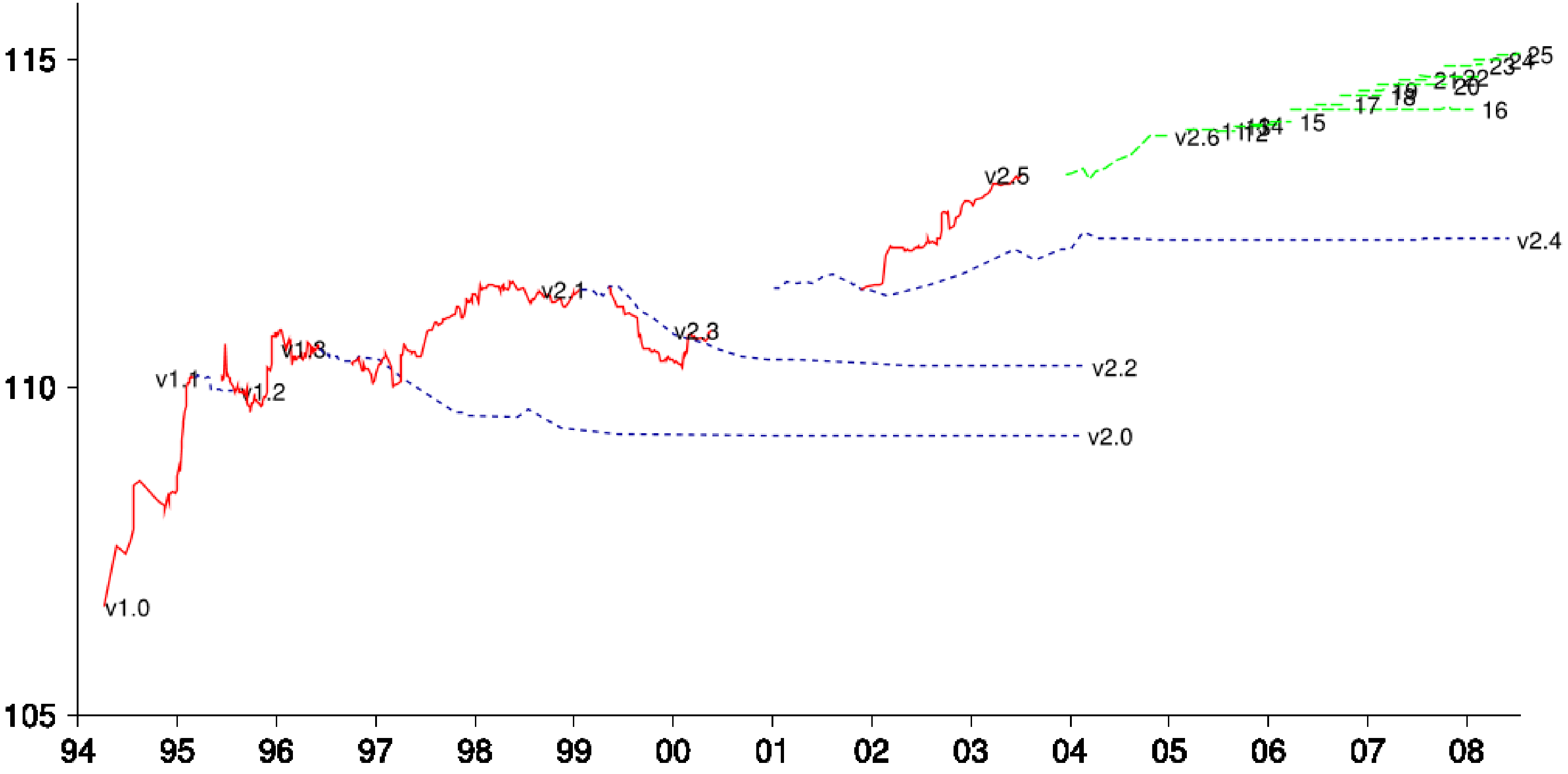
- Defect density
- Active files

Avg. CC per function in Linux Kernel



the reduced average value is just a result of having more functions with relatively lower complexity.

Maintainability index (MI) of Linux Kernel



3 Modular Design and Modularity Principles

Modular programming

- **Modular programming is** a software design technique that **emphasizes separating the functionality of a program into independent, interchangeable modules,** such that each contains everything necessary to execute only one aspect of the desired functionality.
- **It usually refers to high-level decomposition of the code of an entire program into pieces, and has been widely adopted in both Structured Programming and OOP.**
  - Structured programming refers to the low-level code use of structured control flow; 结构化控制流中低层代码的使用
  - Object-oriented programming refers to the data use of objects, a kind of data structure. 对象的数据使用方式

Modular programming

- **The goal of design is to partition the system into modules and assign responsibility among the components in a way that:**
  - High cohesion within modules
  - Loose coupling between modules
- **Modularity reduces the total complexity a programmer has to deal with at any one time assuming:**
  - Functions are assigned to modules in away that groups similar functions together (Separation of concerns)
  - There are small, simple, well-defined interfaces between modules (Information hiding)
- **The principles of cohesion and coupling are probably the most important design principles for evaluating the maintainability of a design.**

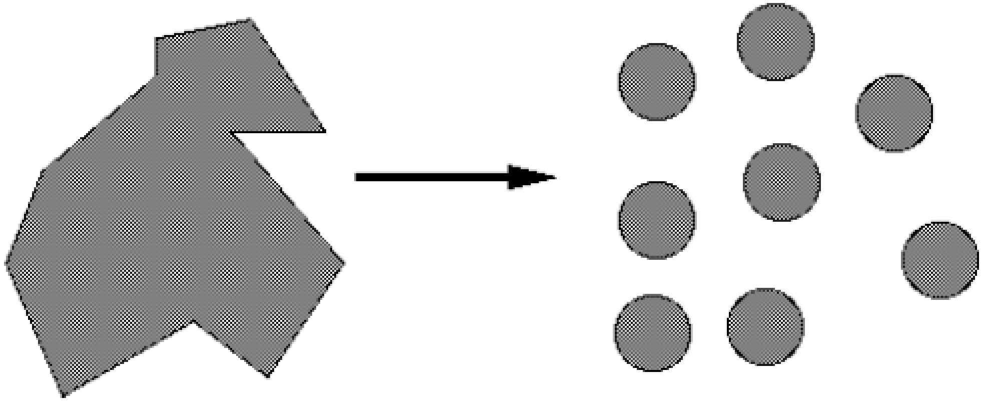
(1) Five Criteria for Evaluating Modularity

Five Criteria for Evaluating Modularity

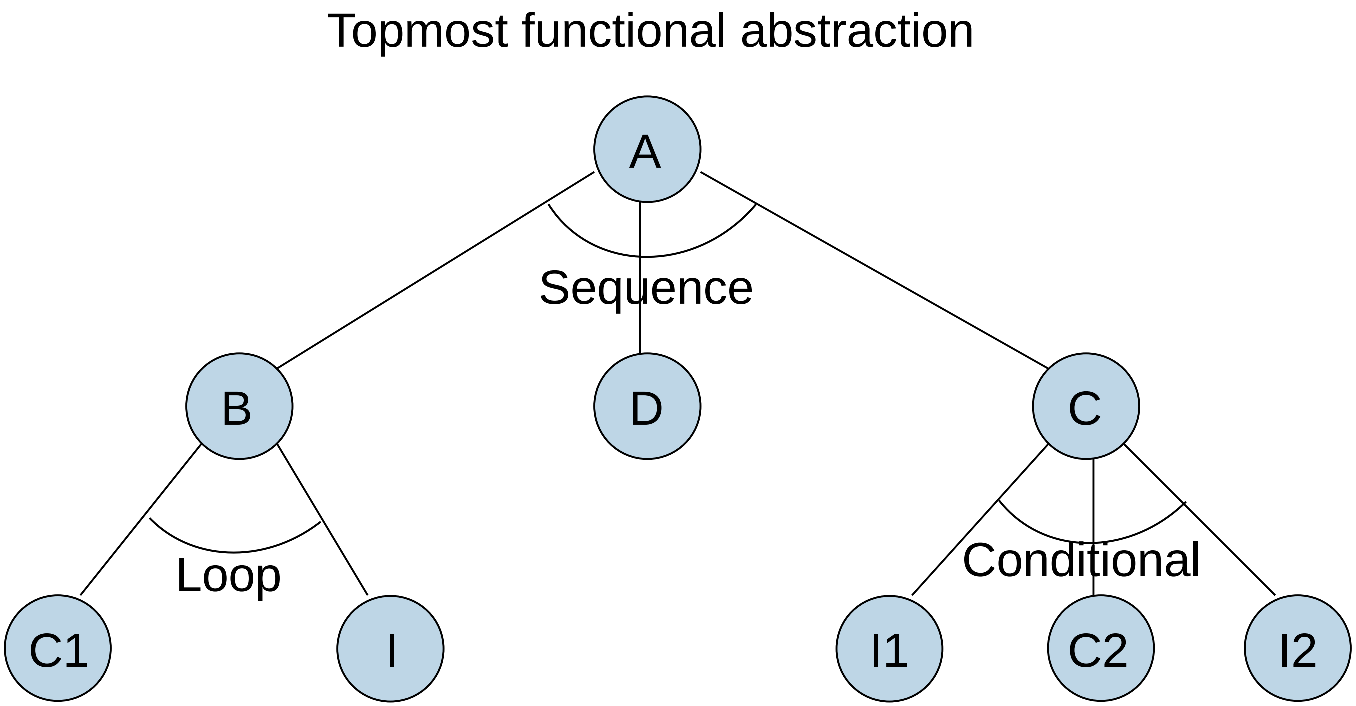
- **Decomposability (可分解性)**
  - Are larger components decomposed into smaller components?
- **Composability (可组合性)**
  - Are larger components composed from smaller components?
- **Understandability (可理解性)**
  - Are components separately understandable?
- **Continuity (可持续性)**
  - Do small changes to the specification affect a localized and limited number of components?
- **Protection (出现异常之后的保护)**
  - Are the effects of run-time abnormalities confined to a small number of related components?

1. Decomposability

- **Decompose problem into smaller sub-problems that can be solved separately (将问题分解为各个可独立解决的子问题)**
  - Goal: keep dependencies explicit and minimal (目标：使模块之间的依赖关系显式化和最小化)
  - Example: top-down structural design

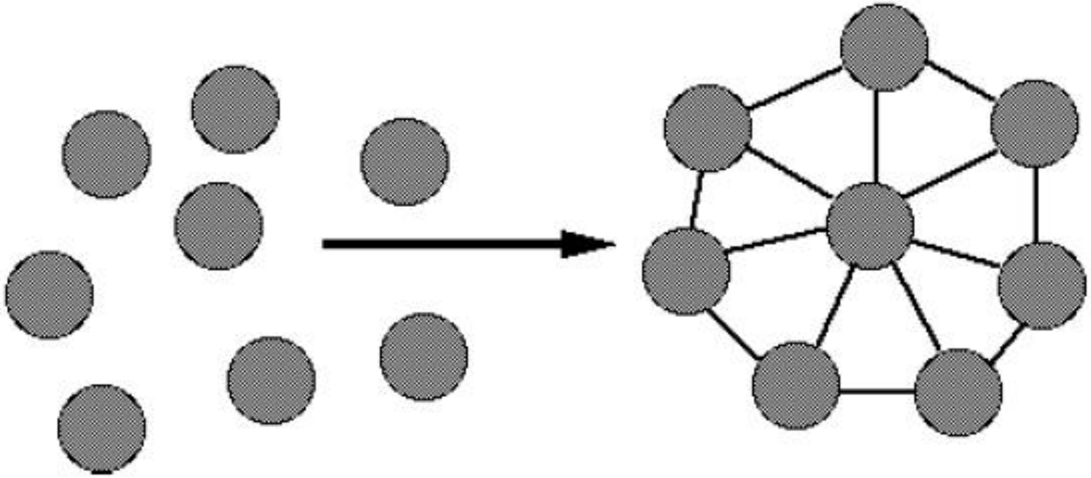


Top-down functional design



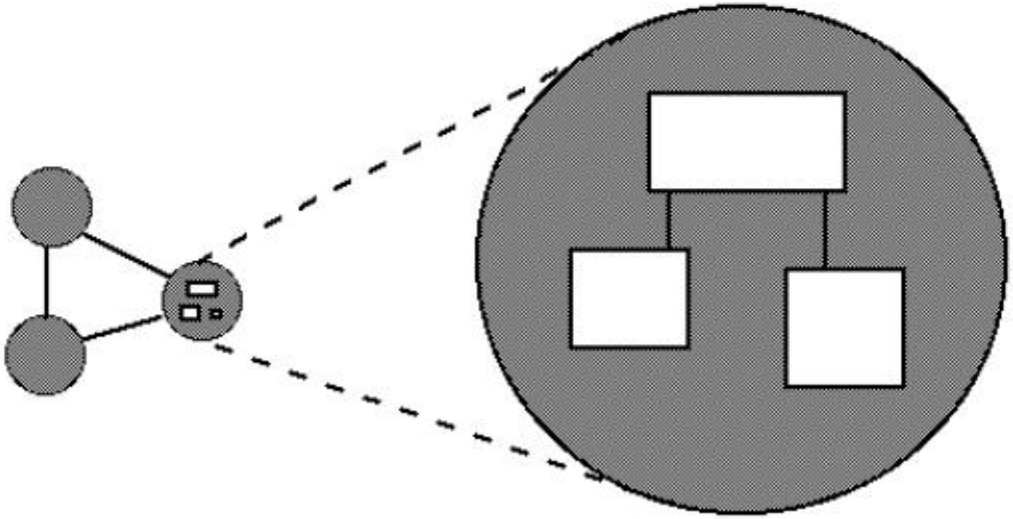
2. Composability

- **Freely combine modules to produce new systems (可容易的将模块组合起来形成新的系统)**
  - Goal: make modules reused in different environments (目标：使模块可在不同的环境下复用)
  - Example: Math libraries; UNIX command & pipes



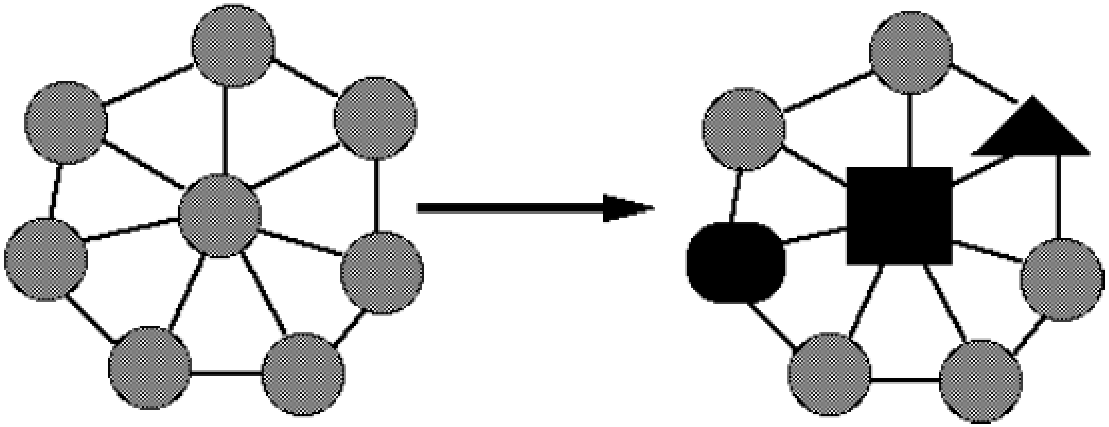
3. Understandability

- **Individual modules understandable by human reader (每个子模块都可被系统设计者容易的理解)**
  - Example: Unix shell such as Program1 | Program2 | Program3
  - Counter-example: Sequential Dependencies (A →B → C)



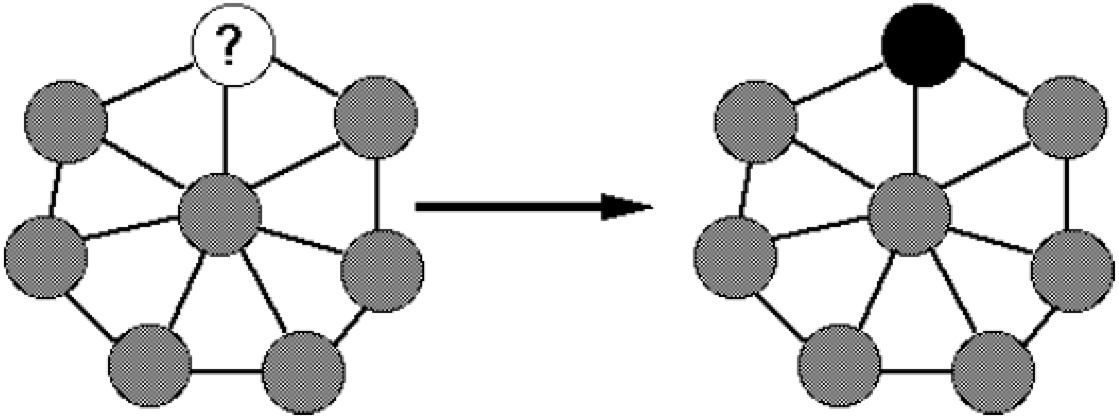
4. Continuity

- **Small change in specification results in:**
  - changes in only a few modules and does not affect the architecture (小的变化将只影响一小部分模块，而不会影响整个体系结构)
  - Example: Symbolic Constants (符号型变量)
    - const String PRODUCT_CODE = “PBS001291A”
  - Example: **Principle of Uniform Access**(It states "All services offered by a module should be available through a uniform notation, which does not betray whether they are implemented through storage or through computation)模块提供的所有服务应该通过统一标识提供



5. Protection

- **Effects of an abnormal run-time condition is confined to a few modules (运行时的不正常将局限于小范围模块内)**
  - Example: Validating input at source



(2) Five Rules of Modularity Design

Five Rules of Modularity Design

- **Direct Mapping (直接映射)**
- **Few Interfaces (尽可能少的接口)**
- **Small Interfaces (尽可能小的接口)**
- **Explicit Interfaces (显式接口)**
- **Information Hiding (信息隐藏)**

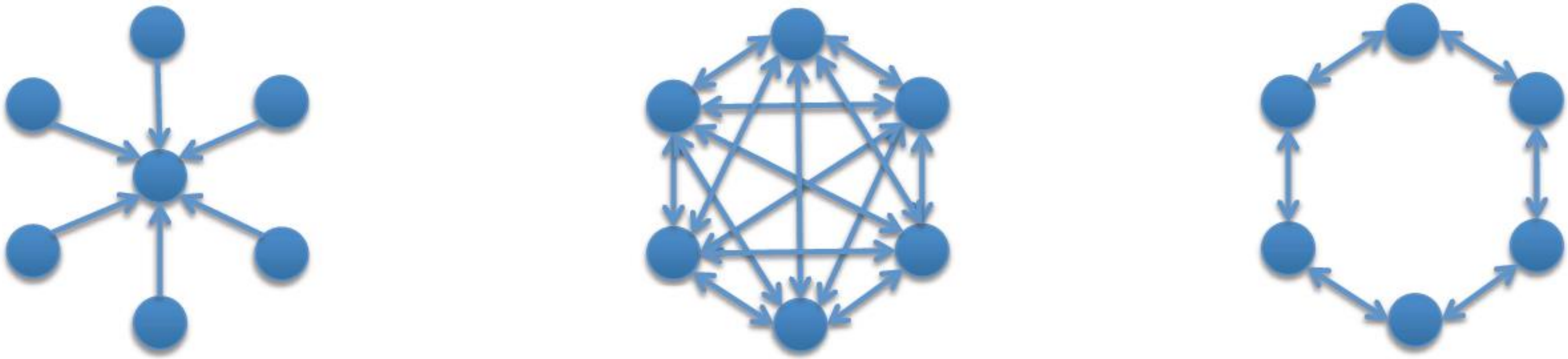
1. Direct Mapping

- **Direct mapping: keep the structure of the solution compatible with the structure of the modeled problem domain (直接映射：模块的结构与现实世界中问题领域的结构保持一致)**

- **Impact on (对以下评价标准产生影响):**
  - Continuity (持续性)
    - easier to assess and limit the impact of change
  - Decomposability (可分解性)
    - decomposition in the problem domain model as a good starting point for the decomposition of the software

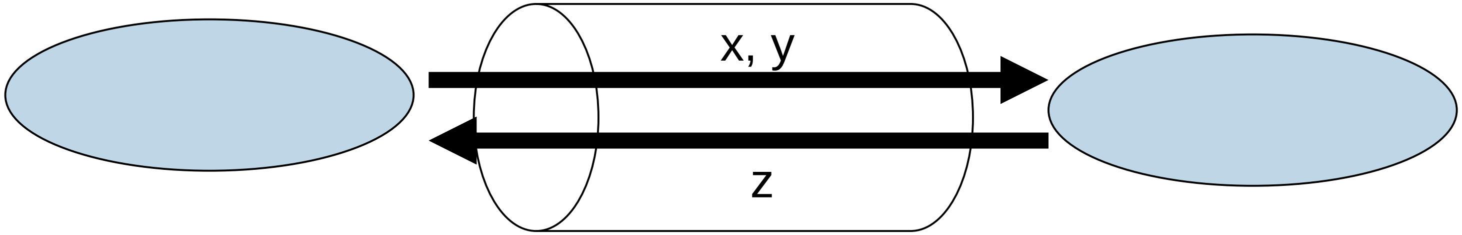
2. Few Interfaces

- **Every module should communicate with as few others as possible (模块应尽可能少的与其他模块通讯)**
  - 通讯路径的数目: n-1, n(n-1)/ 2, n-1
  - affects Continuity, Protection, Understandability and Composability (对以下评价标准产生影响：可持续性、保护性、可理解性、可组合性)



3. Small Interfaces

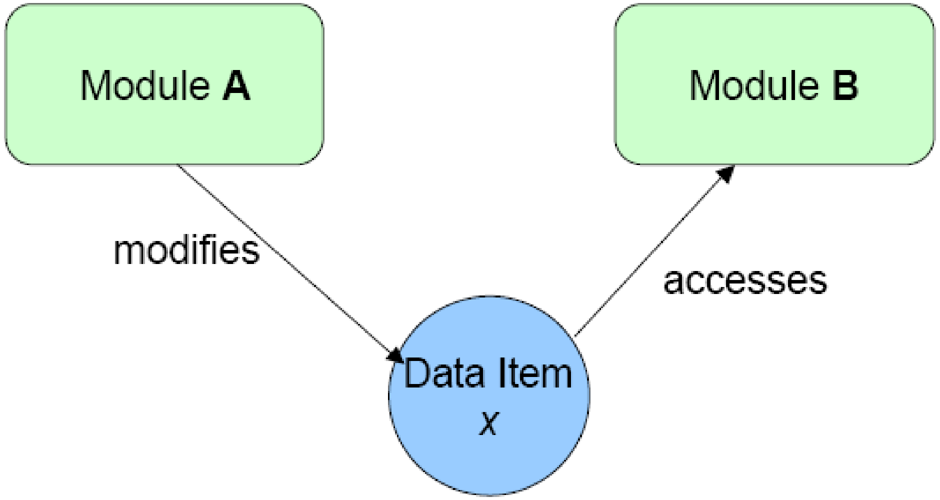
- **If two modules communicate, they should exchange as little information as possible (如果两个模块通讯，那么它们应交换尽可能少的信息)**
  - limited “bandwidth” of communication (限制模块之间通讯的“带宽”)
  - Continuity and Protection (对“可持续性”和“保护性”产生影响)



4. Explicit Interface

- **Whenever two modules A and B communicate, this must be obvious from the text of A or B or both (当A与B通讯时，应明显的发生在A与B的接口之间)**
  - Decomposability, Composability, Continuity, Understandability (受影响的评价标准：可分解性、可组合性、可持续性、 可理解性)

反例：



…再次强调Rule 2-3-4

- **(2) Few Interfaces:** *"Don't talk to many!"*

  尽可能少的接口："不要对太多人讲话…"

- **(3) Small Interfaces:** *"Don't talk a lot!"*

  尽可能小的接口： "不要讲太多…"

- **(4) Explicit Interfaces:** *"Talk loud and in public! Don't whisper!"*

  显式接口： "公开的大声讲话…不要私下嘀咕…"

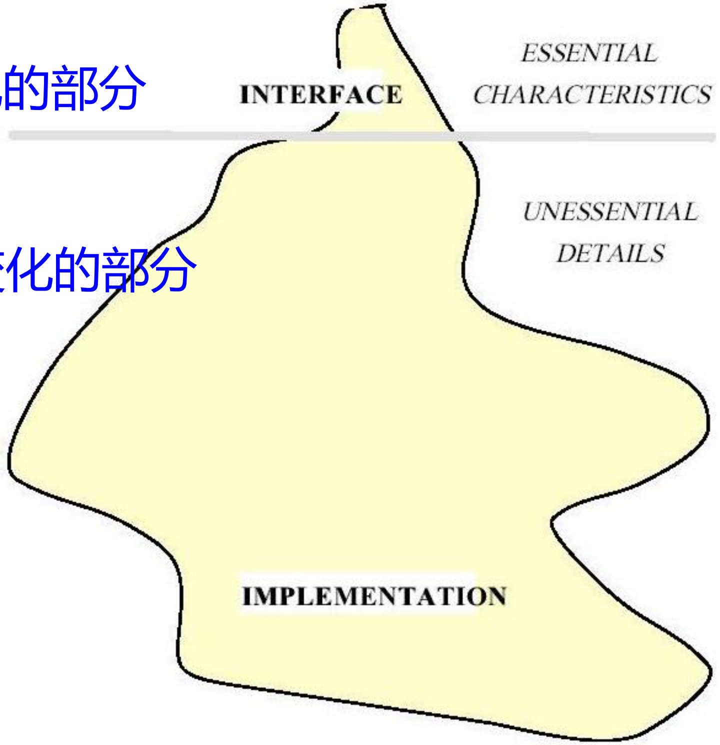
5. Information Hiding

- **Motivation: design decisions that are subject to change should be hidden behind abstract interfaces (经常可能发生变化的设计决策应尽可能隐藏在抽象接口后面)**
  - Impact on Continuity

    (影响“可持续性”)

较少发生变化的部分

需要经常发生变化的部分



- **The designer of every module must select a subset of the module’s properties as the official information about the module, to be made available to client modules.**

Example 1: Comparing the two designs

Design 1:

```
class PersistentData {

    public ResultSet read(string sql);

    // write returns the number of rows effected
    public int write(string sql);

}


PersistentData db = new PersistentData();
db.write(“UPDATE Employees SET Dependents = 2
          WHERE EmployeeID = 47”);
```

Example 1

Design 2:

```
class EmployeeGateway {

    public static EmployeeGateway find(int ID);
    public void setName(string name);
    public string getName();
    public void setDependents(int dependents);
    public int getDependents();
    public int insert();
    public void update();
    public void delete();

}


EmployeeGateway e = EmployeeGateway.find(47);
e.setDependents(2);
e.update();
```

Example 2

```
class Course {
    private Set students;
    public Set getStudents() {
        return students;
    }
    public void setStudents(Set s) {students = s;}
}

--------------------------------------------------------------------------

class Course {
    private Set students;
    public Set getStudents() {
        return Collections.unmodifiableSet(students);
    }
    public void addStudent(Student student) {
        students.add(student);
    }
    public void removeStudent(Student student) {
        students.remove(student);
    }
}
```

(3) Coupling and Cohesion

Coupling

- **Coupling is the measure of dependency between modules. A dependency exists between two modules if a change in one could require a change in the other.**
- **The degree of coupling between modules is determined by:**
  - The number of interfaces between modules (quantity), and
  - Complexity of each interface (determined by the type of communication) (quality)

Example: coupling between CSS and JavaScript

- **A well-designed web app modularizes around:**
  - HTML files which specify data and semantics
  - CSS rules which specify the look and formatting of HTML data
  - JavaScript which defines behavior/interactivity of page
- **Assume you have the following HTML and CSS definitions.**

Example: coupling between CSS and JavaScript

- **HTML:**

```
<!doctype html>
<html>
<head>
  <script type="text/javascript" src="base.js"></script>
  <link rel="stylesheet" href="default.css">
</head>
<body>
  <button onclick="highlight2()">Highlight</button>
  <button onclick="normal2()">Normal</button>
  <h1 id="title" class="NormalClass">CSS <--> JavaScript Coupling</h1>
</body>
</html>
```

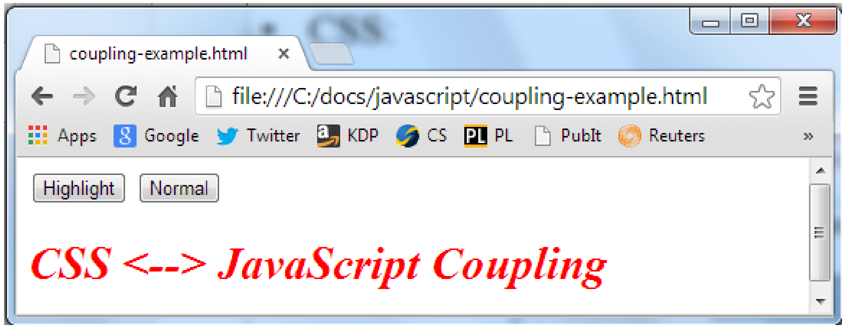
coupling-example.html

- **CSS:**

```
.NormalClass {
  color:inherit;
  font-style:normal;
}
```

default.css

- **Output:**



CSS <--> JavaScript Coupling

Option A

- **JavaScript code modifies the style attribute of HTML element.**

```
function highlight() {
    document.getElementById("title").style.color="red";
    document.getElementById("title").style.fontStyle="italic";
}

function normal() {
    document.getElementById("title").style.color="inherit";
    document.getElementById("title").style.fontStyle="normal";
}
```

base.js

Option B

- **JavaScript code modifies the class attribute of HTML element.**

```
function highlight() {
    document.getElementById("title").className = "HighlightClass";
}

function normal() {
    document.getElementById("title").className = "NormalClass";
}
```

base.js

```
.NormalClass {
  color:inherit;
  font-style:normal;
}

.HighlightClass {
  color:red;
  font-style:italic;
}
```

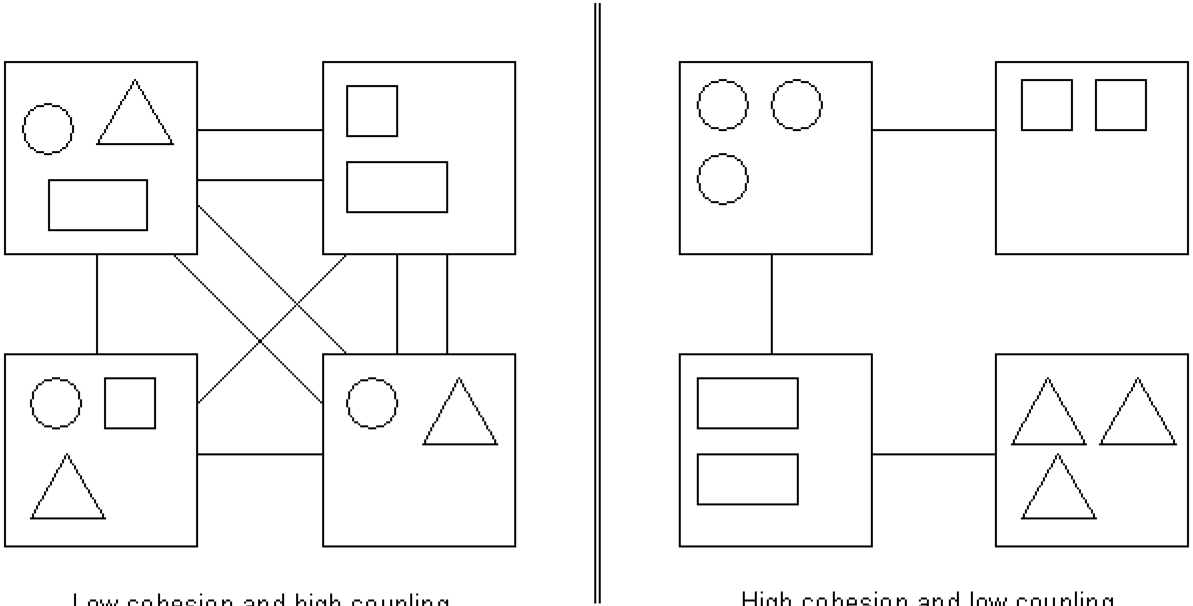
default.css

Cohesion

- **Cohesion is a measure of how strongly related the functions or responsibilities of a module are.**
- **A module has high cohesion if all of its elements are working towards the same goal.**

Cohesion and Coupling

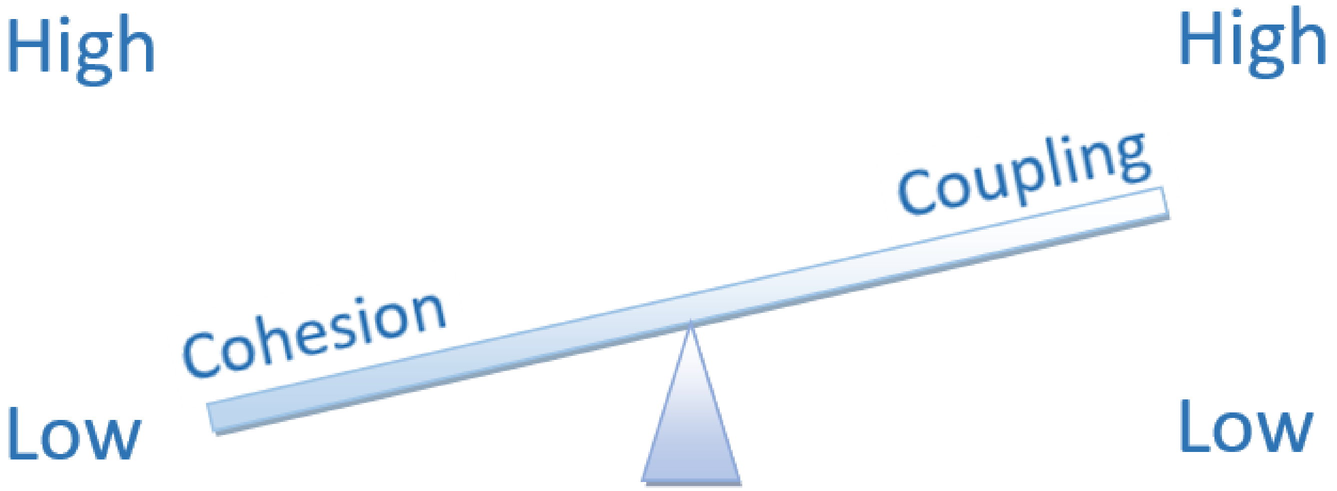
- **The best designs have high cohesion (also called strong cohesion) within a module and low coupling (also called weak coupling) between modules.**



Low cohesion and high coupling

High cohesion and low coupling

Coupling and Cohesion are with trade-off



- **When Coupling is high, cohesion tends to be low and vise versa.**

4 OO Design Principles: SOLID

SOLID

- **(SRP) The Single Responsibility Principle** 单一责任原则
- **(OCP) The Open-Closed Principle** 开放封闭原则
- **(LSP) The Liskov Substitution Principle** Liskov替换原则
- **(ISP) The Interface Segregation Principle** 接口隔离原则
- **(DIP) The Dependency Inversion Principle** 依赖转置原则

- **SOLID**

- 参考资料《敏捷软件开发:原则、模式与实践》， Robert C. Martin，人民邮电出版社

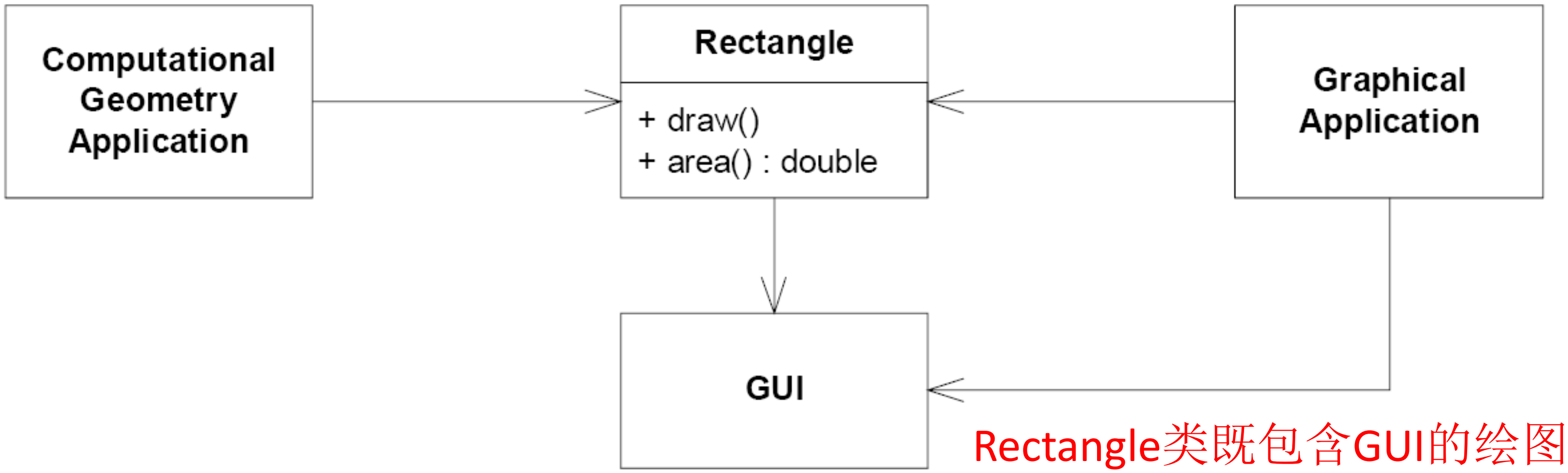
(1) Single responsibility principle (SRP)

Single Responsibility Principle

- **"There should never be more than one reason for a class to change", i.e., a class should concentrate on doing one thing and one thing only. 引起类变化的原因只有一个，专心做一件事**

Just because you can, doesn't mean you should

SRP的一个反例

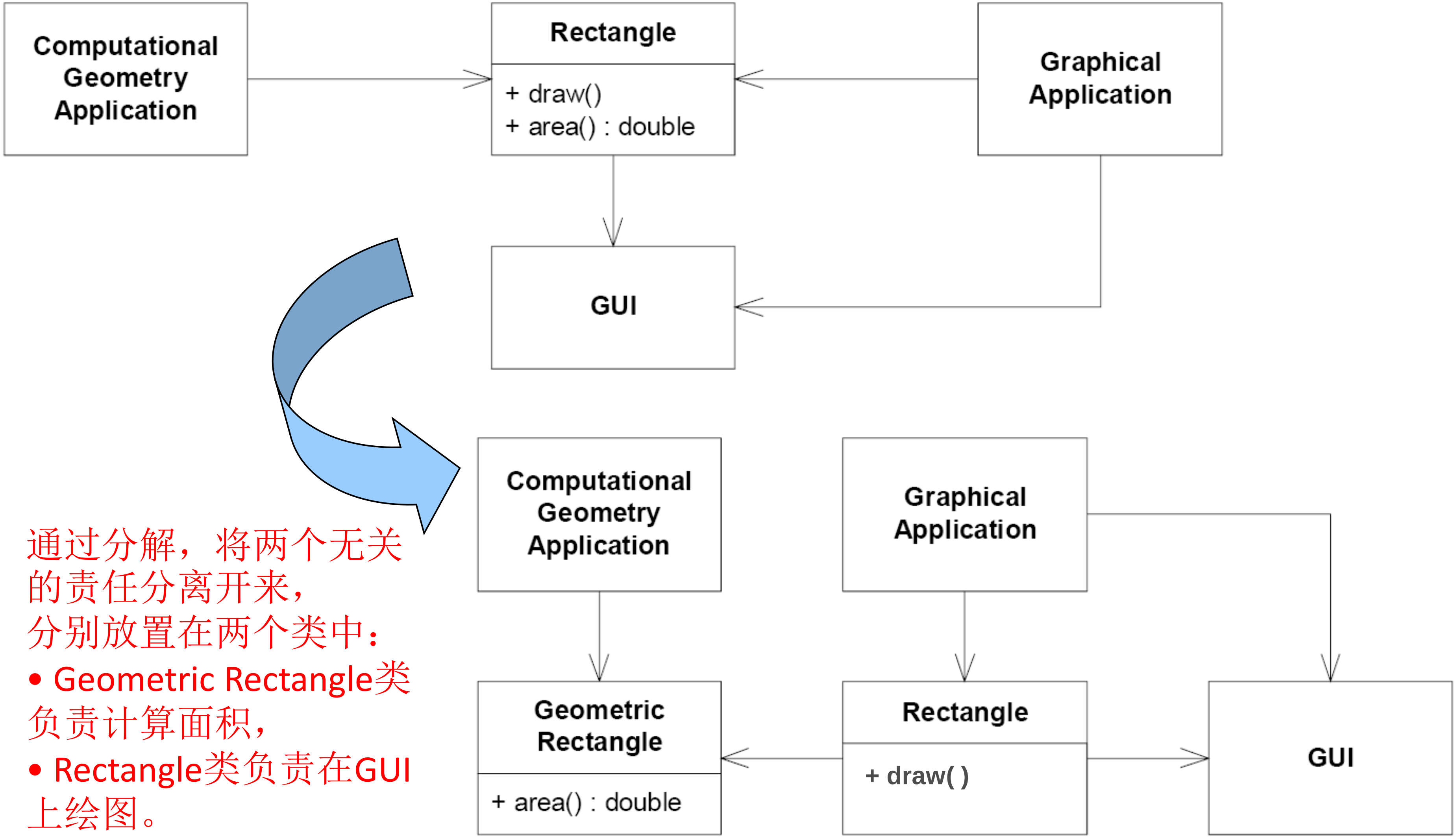


Rectangle类既包含GUI的绘图功能draw()--在GUI上显示矩形，
又包括几何计算功能area()--计算面积。
该设计违反了SRP。

问题1：计算应用ComputeAPP会包含同其无关的GUI代码，如：C++会把GUI代码链接进来，Java则要求GUI的Class文件必须被部署到目标平台上。

问题2：如果GraphicalAPP的改变导致Rectangle需要变化，则ComputerAPP也需要重新构建、测试和部署。

SRP的一个反例



通过分解，将两个无关的责任分离开来，分别放置在两个类中：

- Geometric Rectangle类负责计算面积，
- Rectangle类负责在GUI上绘图。

Single Responsibility Principle

- **Two resposibilities**

```
interface Modem {
 public void dial(String pno);
 public void hangup();

 public void send(char c);
 public char recv();
}
```

- **Connection Management + Data Communication**

Single Responsibility Principle

```
interface DataChannel {
 public void send(char c);
 public char recv();
}
```

```
interface Connection {
 public void dial(String phn);
 public char hangup();
}
```

(2) Open/closed principle (OCP)

Open Closed Principle

- **"Software entities (classes, modules, functions, etc.) should be open for extension, but closed for modification“, i.e., change a class' behavior using inheritance and composition对扩展是开放的，对修改是封闭的，应通过集成和组合改变/扩展功能**
- **Modules should be open and closed.**
- **Definitions:**
  - Open module: May be extended.
  - Closed module: Usable by clients. May be approved, baselined and (if program unit) compiled.
- **The rationales are complementary:**
  - For closing a module (manager’s perspective): Clients need it now.
  - For keeping modules open (developer’s perspective): One frequently overlooks aspects of the problem.

Open Closed Principle

```
// Open-Close Principle - Bad example
 class GraphicEditor {

 public void drawShape(Shape s) {
    if (s.mType==1)
        drawRectangle(s);
    else if (s.mType==2)
        drawCircle(s);
    }
    public void drawCircle(Circle r)
        {....}
    public void drawRectangle(Rectangle r)
        {....}
 }
```

```
class Shape {
    int mType;
 }


class Rectangle extends Shape {
    Rectangle() {
        super.mType=1;
    }
 }

class Circle extends Shape {
    Circle() {
        super.mType=2;
    }
 }
```

Open Closed Principle – a Few Problems….

- **Impossible to add a new** `Shape` **without modifying** `GraphEditor`
- **Important to understand** `GraphEditor` **to add a new** `Shape`
- **Tight coupling between** `GraphEditor` **and** `Shape`
- **Difficult to test a specific** `Shape` **without involving** `GraphEditor`
- `If-Else-/Case` **should be avoided**

Open Closed Principle - Improved

```
// Open-Close Principle - Good example


class GraphicEditor {
   public void drawShape(Shape s) {
     s.draw();
   }
}

class Shape {
   abstract void draw();
}

class Rectangle extends Shape {
   public void draw() {
   // draw the rectangle
   }
}
```

Single Choice

- **Whenever a software system must support a set of alternatives, one and only one module in the system should know their exhaustive list.** 只要软件系统必须支持一组替代方案，系统中的一个且只有一个模块应该知道他们的详尽列表。

- **Editor: set of commands (insert, delete etc.)**
- **Graphics system: set of figure types (rectangle, circle etc.)**
- **Compiler: set of language constructs (instruction, loop, expression etc.)**

(3) Liskov substitution principle (LSP)

Liskov Substitution Principle

- **“Functions that use pointers or references to base classes must be able to use objects of derived classes without knowing it“, i.e., subclasses should behave nicely when used in place of their base class(关注的是“操作”的可替换性)**

- **LSP: Subtypes must be substitutable for their base types. (子类型必须能够替换其基类型)**

Liskov Substitution Principle

```
// Violation of LSP

 class Rectangle {
    int m_width;
    int m_height;

    public void setWidth(int width){
        m_width = width;
    }
    public void setHeight(int h){
        m_height = h;
    }
    public int getWidth(){
        return m_width;
    }
    public int getHeight(){
        return m_height;
    }
    public int getArea(){
        return m_width * m_height;
    }
 }
```

```
class Square extends Rectangle {
    public void setWidth(int width){
        m_width = width;
        m_height = width;
    }

    public void setHeight(int height){
        m_width = height;
        m_height = height;
    }
}
```

Liskov Substitution Principle

```
class LspTest{

   private static Rectangle getNewRectangle(){
       // it can be an object returned by some factory ...
       return new Square();
   }

   public static void main (String args[]){
       Rectangle r = LspTest.getNewRectangle();
       r.setWidth(5);
       r.setHeight(10);

//user knows that r it's a rectangle. It assumes that he's able to set
the width and height as for the base class

       System.out.println(r.getArea());
       // now he's surprised to see that the area is 100 instead of 50.
   }
}
```

(4) Interface segregation principle (ISP)

Interface Segregation Principle

- **"Clients should not be forced to depend upon interfaces that they do not use“, i.e., keep interfaces small. “客户不应该被迫依赖他们不使用的接口”，即保持接口小。**

- **Don’t force classes to implement methods they can’t (Swing/Java)**
- **Don’t pollute interfaces with a lot of methods**
- **Avoid ’fat’ interfaces**

Interface Segregation Principle

```
//bad example (polluted interface)
interface Worker {
    void work();
    void eat();
}
```

```
ManWorker implements Worker {
    void work() {…};
    void eat() {30 min break;};
}
```

```
RobotWorker implements Worker {
    void work() {…};
    void eat() {//Not Appliciable
                 for a RobotWorker};
}
```

Interface Segregation Principle

- **Solution: split into two interfaces**

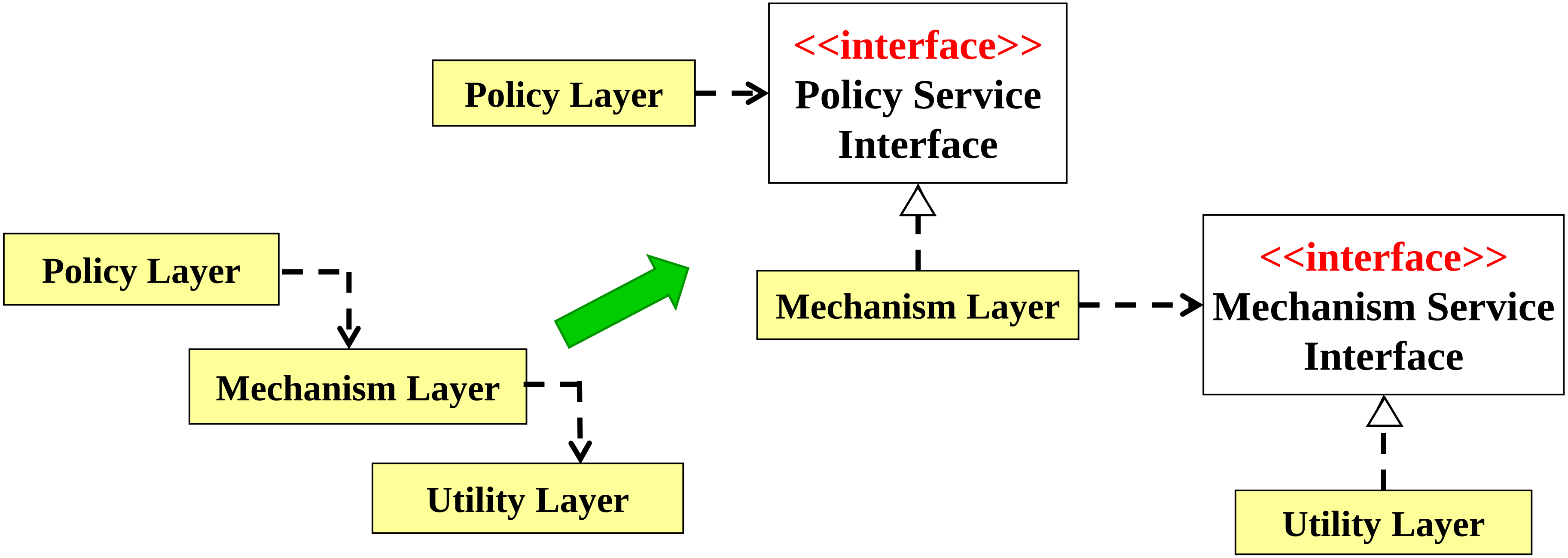
```
interface Workable {
   public void work();
}

interface Feedable{
   public void eat();
}
```

(5) Dependency inversion principle (DIP)

Dependency Inversion Principle

- "A. High level modules should not depend upon low level modules. Both should depend upon abstractions.高层模块不应该依赖于低层模块,二者都应该依赖于抽象。
- B. Abstractions should not depend upon details. Details should depend upon abstractions“, i.e., use lots of interfaces and abstractions. 抽象不应该依赖于实现细节,实现细节应该依赖于抽象。



Dependency Inversion Principle

```
//DIP - bad example
public class EmployeeService {
        private EmployeeFinder emFinder //concrete class, not abstract.
        //Can access a SQL DB for instance
        public Employee findEmployee(…) {
                emFinder.findEmployee(…)
        }
}
```

Dependency Inversion Principle

```
//DIP - fixed
public class EmployeeService {
        private IEmployeeFinder emFinder
        //depends on an abstraction, no an implementation

        public Employee findEmployee(…) {
           emFinder.findEmployee(…)
        }
}
```

- **Now its possible to change the finder to be a XmEmployeeFinder, DBEmployeeFinder, FlatFileEmployeeFinder, MockEmployeeFinder….**

Why DIP?

- **Advantages:**
  - Formalize class contracts.
  - You can define the services of a routine in terms of pre- and post-conditions. This makes it very clear what to expect.

- **Try Design for Testing**
  - Create a test-friendly design
  - A test-friendly module is likely to exhibit other important design characteristics.
  - Example: you would avoid circular dependencies. Business logic will be better isolated from UI code if you have to test it separately from the UI

5 OO Design Principles: GRASP

What's GRASP patterns

- **General Responsibility Assignment Software Patterns (principles), abbreviated GRASP, consist of guidelines for assigning responsibility to classes and objects in OOP.通用责任分配软件模式（原则）**

- **The GRASP patterns are a learning aid to help one understand essential object design, and apply design reasoning in a methodical, rational, explainable way.**
- **This approach to understanding and using design principles is based on patterns of assigning responsibilities to classes.**

《Applying UML and Patterns》

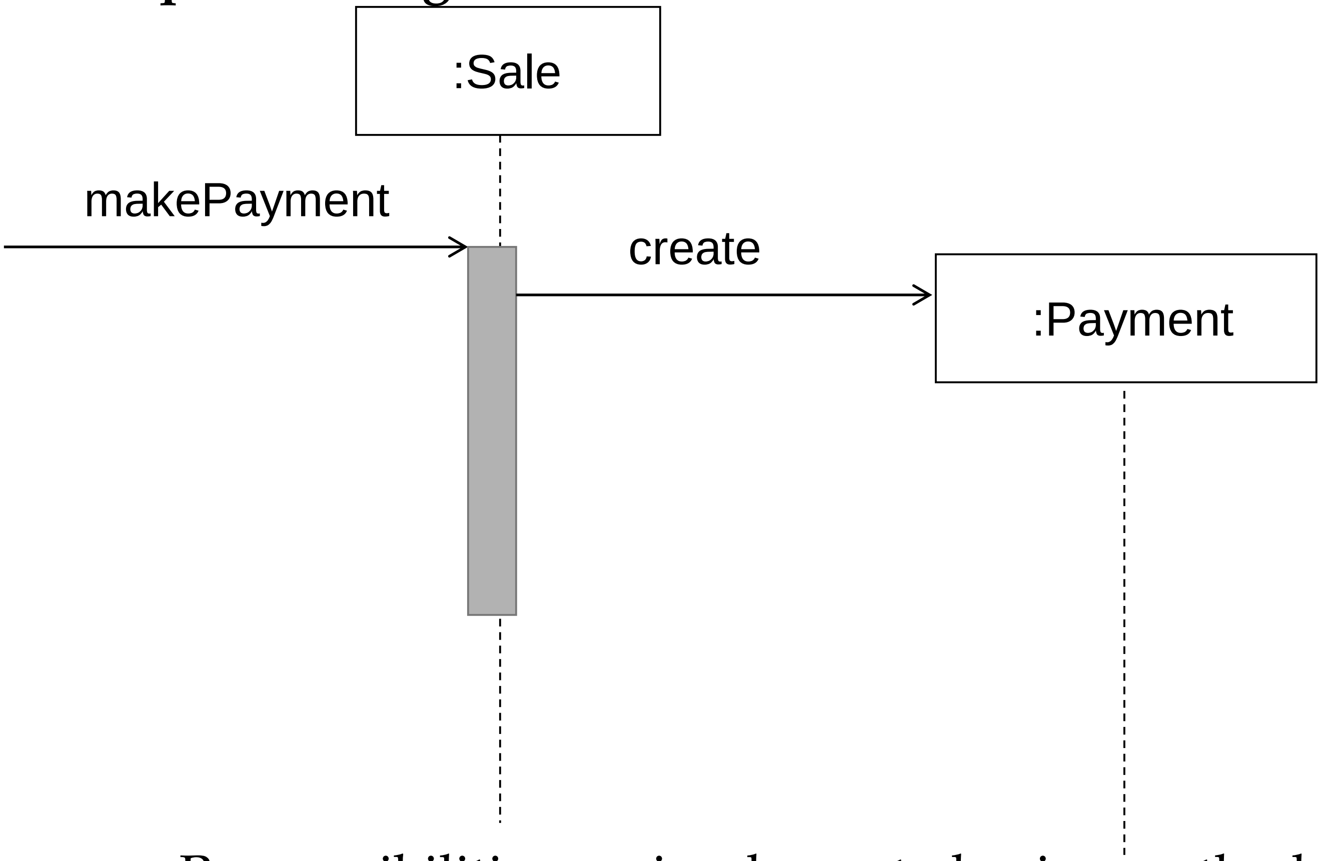
What's responsibility

- **Responsibility of an object: related to the obligations of an object**
  对象的责任：对象的义务

- **Knowing:**
  - Knowing about private encapsulated data
  - Knowing about related objects
  - Knowing about things it can derive or calculate
- **Doing:**
  - Doing something itself, such as creating an object or doing a calculation
  - Initiating action in other objects
  - Controlling and coordinating activities in other objects.

Responsibilities and methods

- **UML Sequence Diagram**



Responsibilities are implemented using methods:
`makePayment` implies `Sale` object has a responsibility to create a `Payment` object

Responsibilities and Interaction Diagrams

- **Interaction diagrams(includes Sequence Diagram and Collaboration Diagram) show choices in assigning responsibilities to objects.**
- **GRASP patterns guide choices in where to assign responsibilities.**
- **GRASP patterns are a codification of widely used basic principles.**

What is GRASP composed of?

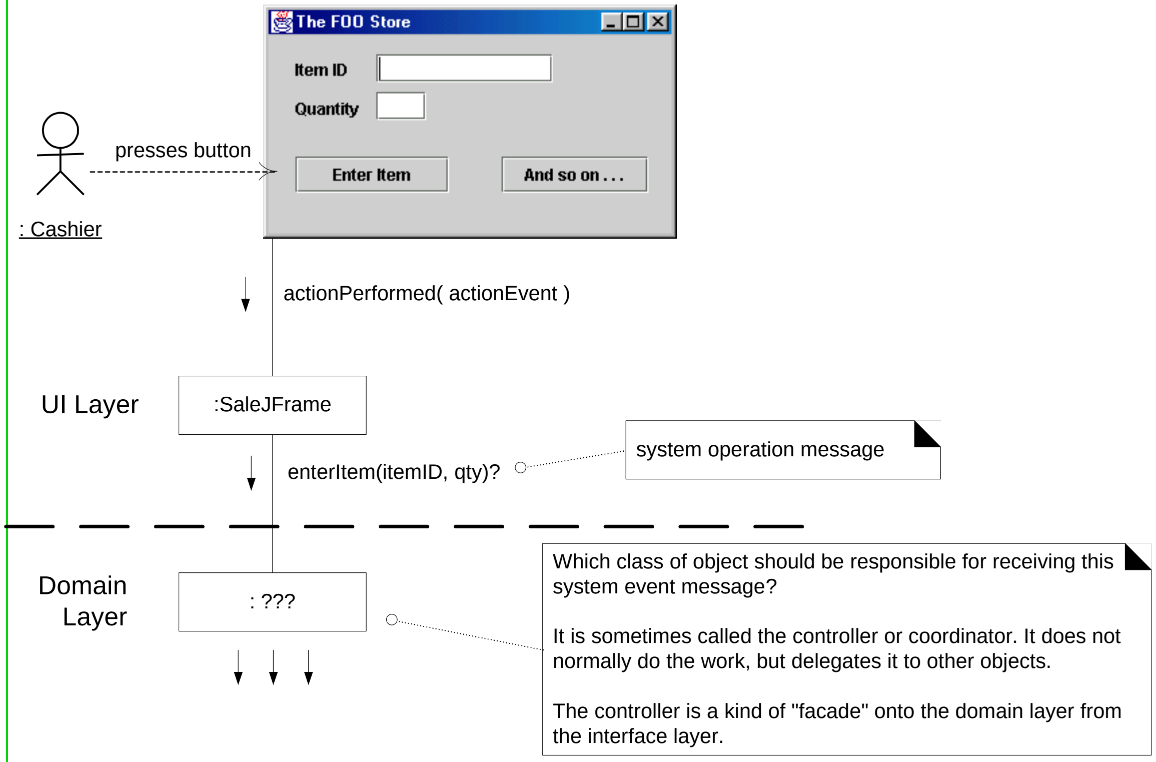
- **Controller**
- **Information expert**
- **Creator**
- **Low coupling**
- **High cohesion**
- **Indirection**
- **Polymorphism**
- **Protected variations**
- **Pure fabrication**

(1) Controller

- **Problem :**
  - Who should be responsible for handling an input system event ?
- **Solution:**
  - **Assign the responsibility for receiving or handling a system event message to a class representing one of the following choices:**
    - 1. Represent the overall system, device or subsystem (Façade controller外观控制器)
    - 2. Represent a use case scenario within which the system events occur. Often named <UseCaseName>Handler or <UseCaseName>Session
      - Use the same controller for all system events in the same use case scenario
- **Guideline:**
  - Normally, a controller should *delegate* to other objcets the work that needs to be done; it coordinates or controls the activity. It does not do much work itself.

Example of Controller pattern

- **Who should be the controller for system events ?**



system operation message

Which class of object should be responsible for receiving this system event message?

It is sometimes called the controller or coordinator. It does not normally do the work, but delegates it to other objects.

The controller is a kind of "facade" onto the domain layer from the interface layer.

The Controller pattern suggest :

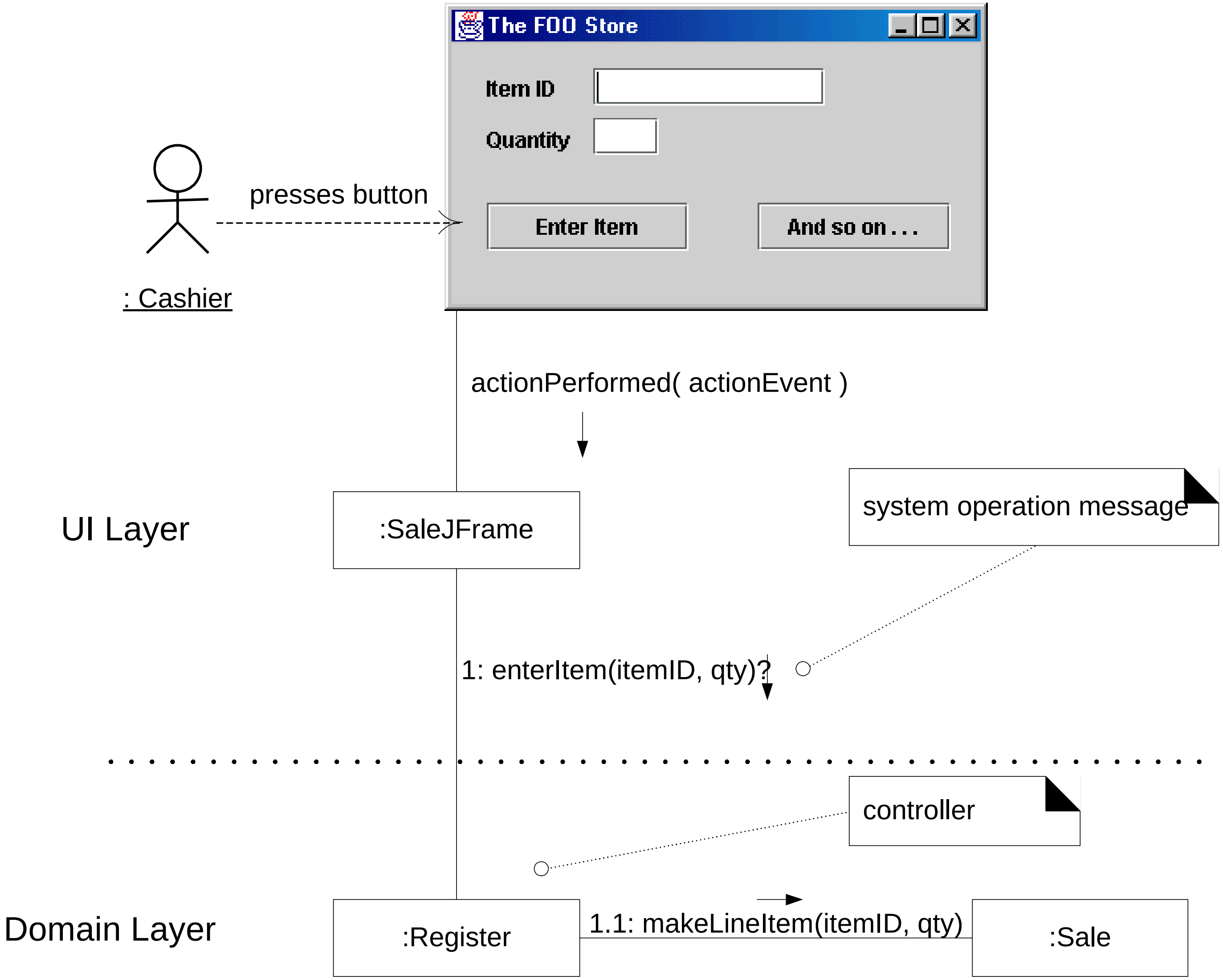
- •Solution1: A Facade controller
  - •Register
  - •POSSystem
- •Solution2: A receiver or handler of all system events of a use case scenario
  - •ProcessSaleHandler
  - •ProcessSaleSession

哪个对象的类应该负责接收系统事件消息?

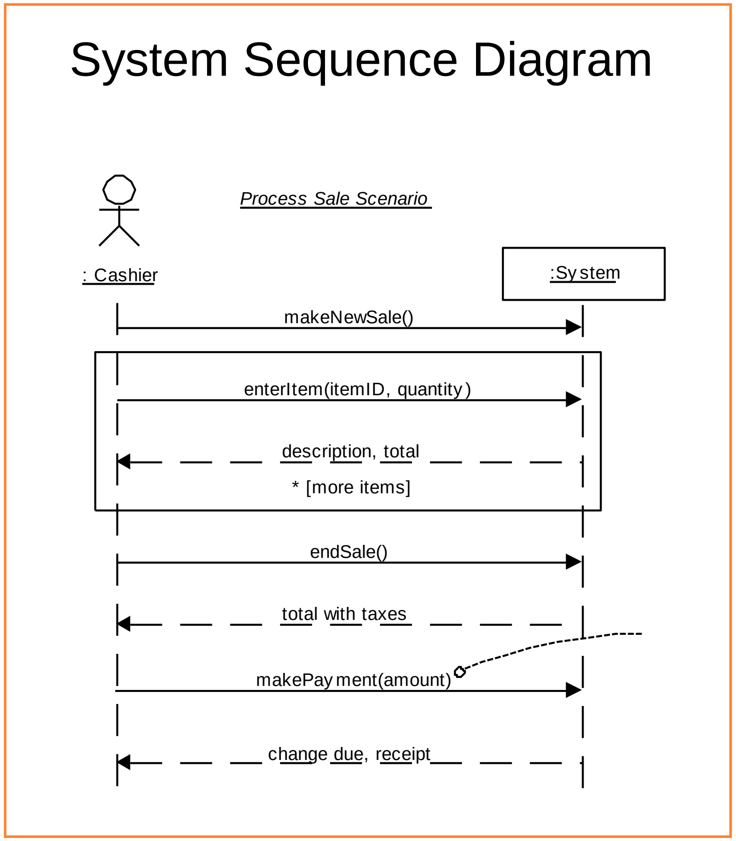
有时称为控制器或者协调器，它通常不完成工作，而是将工作委派给其他对象。（委托模式）

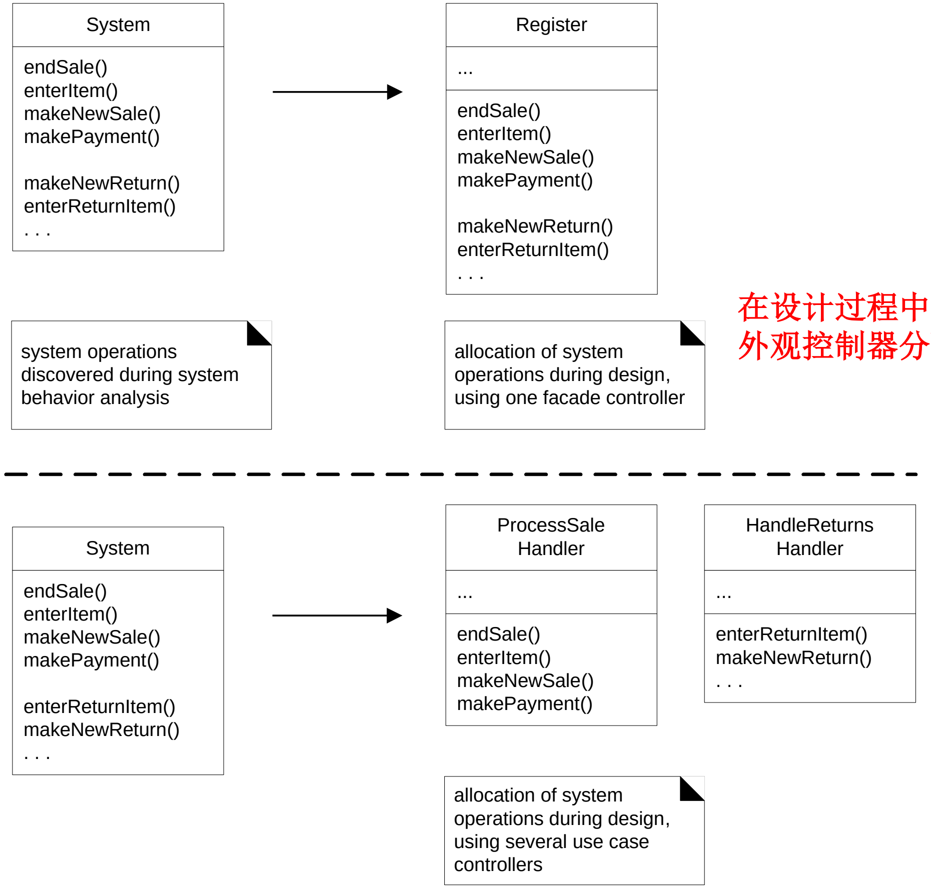
该控制器是从界面层到领域层的一种“外观”

Facade Controller



System events and Allocating system operations


System Sequence Diagram


System
endSale()
enterItem()
makeNewSale()
makePayment()

makeNewReturn()
enterReturnItem()
. . .

Register
...
endSale()
enterItem()
makeNewSale()
makePayment()

makeNewReturn()
enterReturnItem()
. . .

system operations discovered during system behavior analysis

allocation of system operations during design, using one facade controller

在设计过程中使用一个外观控制器分配系统操作

System
endSale()
enterItem()
makeNewSale()
makePayment()

enterReturnItem()
makeNewReturn()
. . .

ProcessSale Handler
...
endSale()
enterItem()
makeNewSale()
makePayment()

HandleReturns Handler
...
enterReturnItem()
makeNewReturn()
. . .

allocation of system operations during design, using several use case controllers

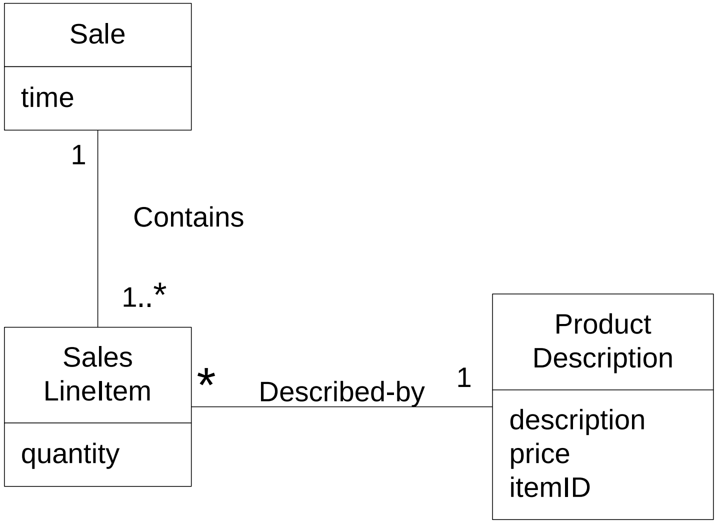
在设计过程中使用若干用例控制器分配系统操作

(2) Information Expert

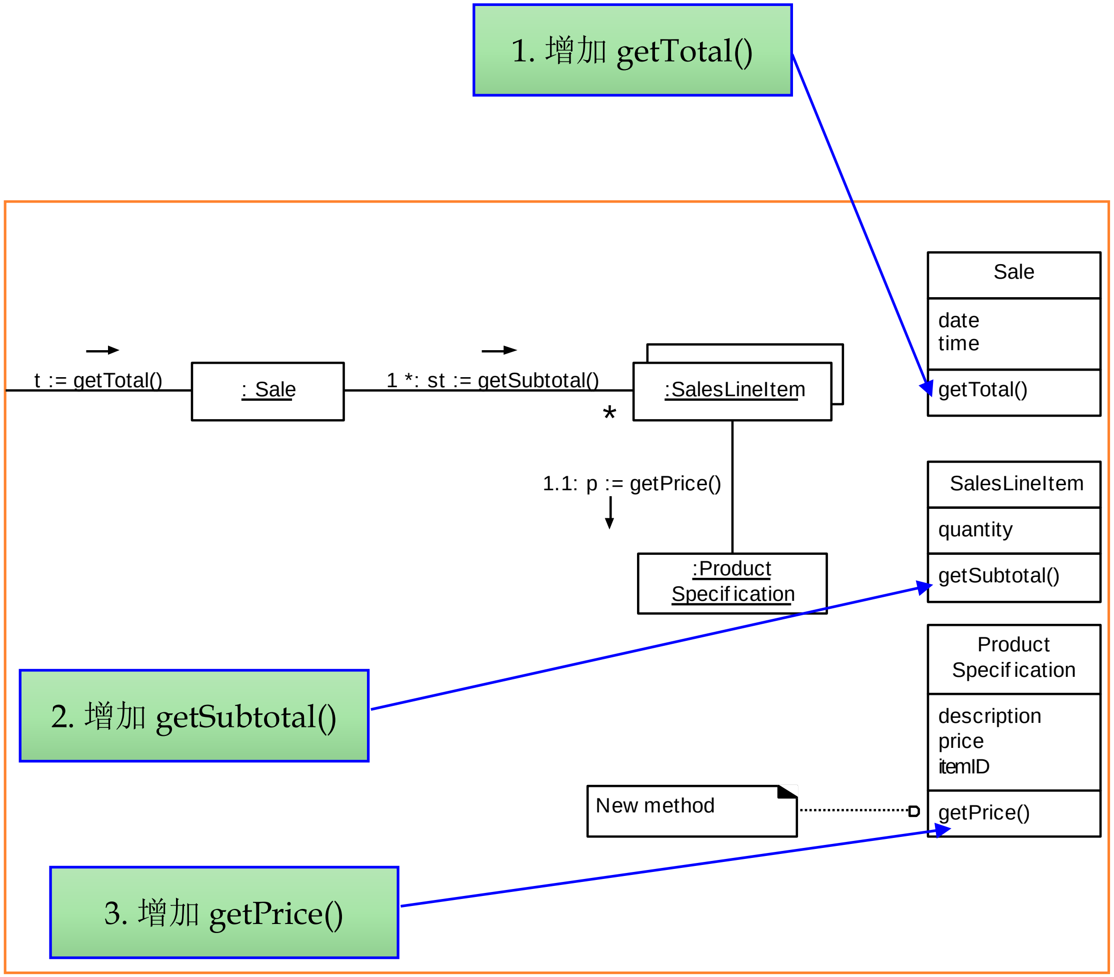
- **Problem: What is a general principle of assigning responsibilities to objects?**
  - Who should be responsible for knowing/doing …?
  - Domain model (domain expert, domain analysis) to design model (software classes).
  - Any existing to any representative.
- **Solution: Assign a responsibility to the information expert – the class that has the information necessary to fulfill the responsibility.**

Example of Information Expert

- **Who should be responsible for knowing the *grand total of a sale* ?**



Design Class	Responsibility
Sale	knows sale total
SalesLineItem	knows line item subtotal
ProductDescription	knows product price


1. 增加 getTotal()

2. 增加 getSubtotal()

3. 增加 getPrice()

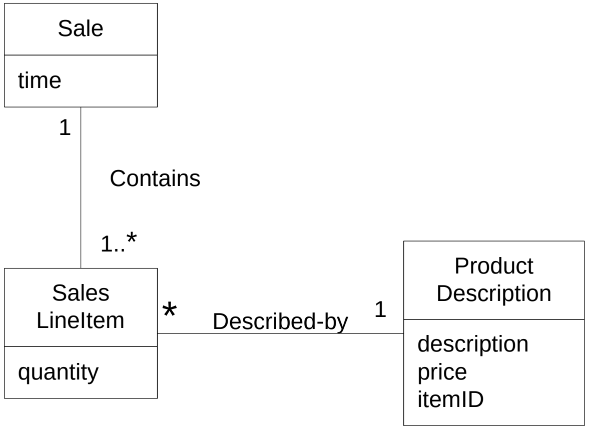
(3) Creator

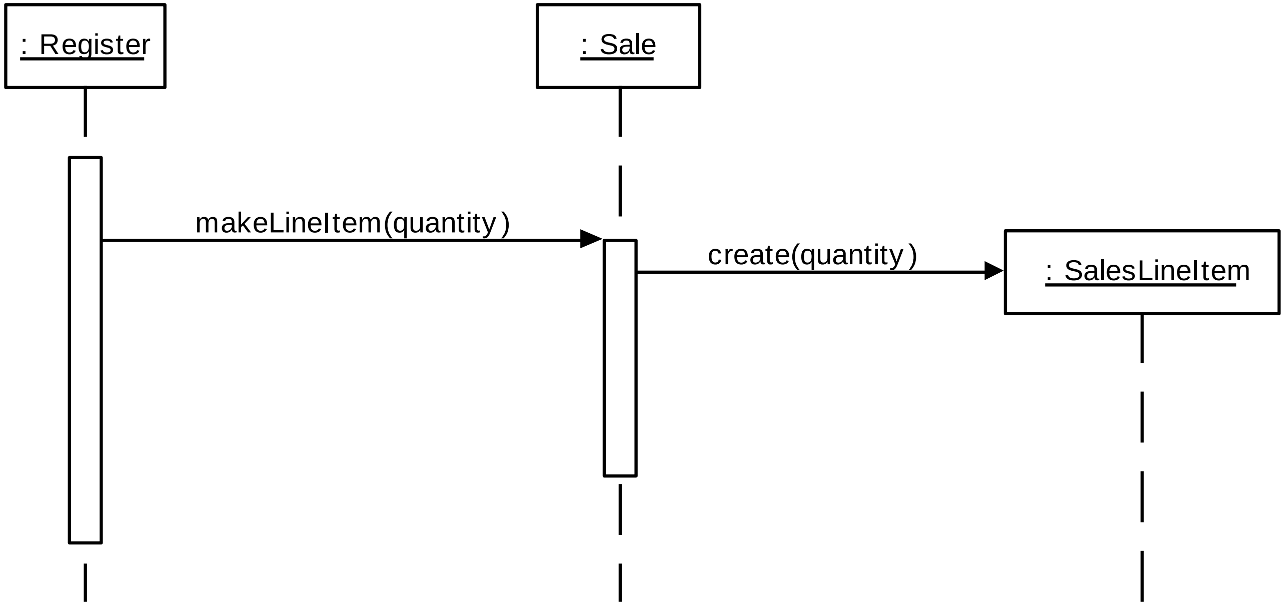
- **Problem :**
  - Who should be responsible for creating a new instance of some class ?

- **Solution: Class B has the responsibility to create an instance of class A if :**
  - B aggregates or “contains” A objects
  - B closely uses A objects
  - B has the initializing data for A
  - B is a creator of A objects.

Example of Creator

- **Who should be responsible for creating a SalesLineItem ?**



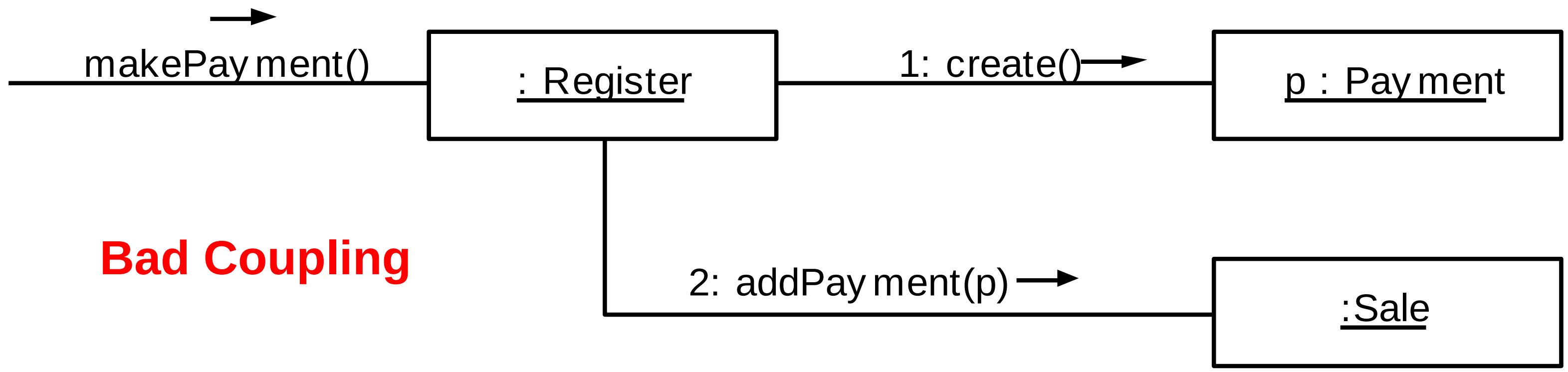


(4) Low Coupling

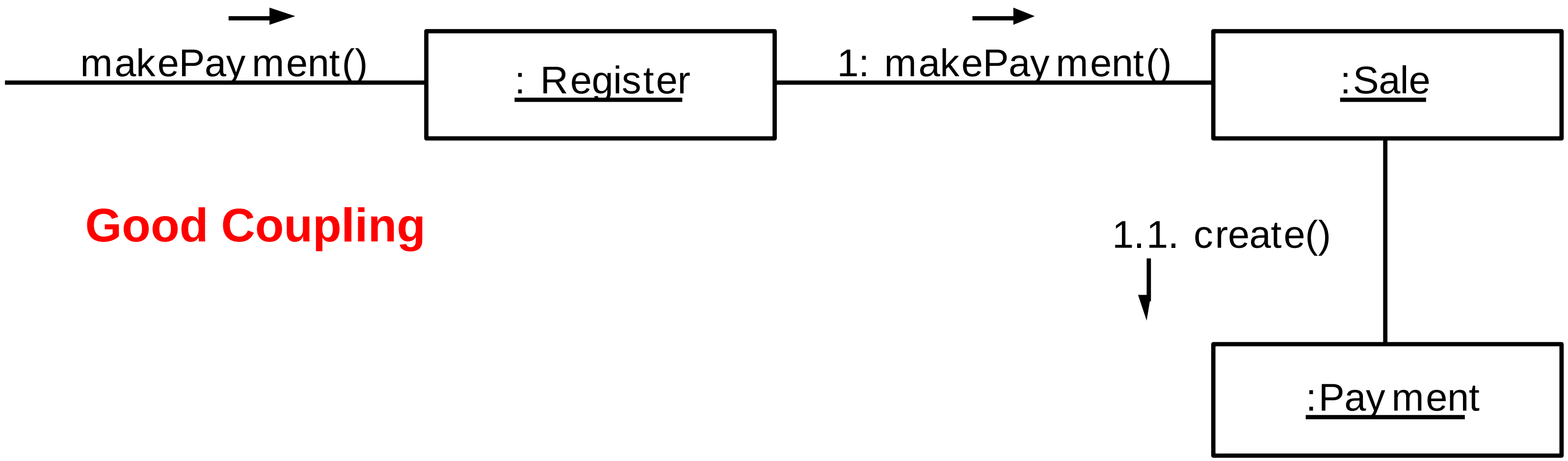
- **Problem :**
  - How to support low dependency, low change impact, and increased reuse?
  - Coupling is a measure of how strongly one element is connected to, has knowledge of, or relies on other elements.
- **Solution:**
  - Assign a responsibility so that coupling remains low.
  - Low Coupling is an evaluative principle. Use this to evaluate alternatives.

Example of Low Coupling

- **Who should be responsible for creating a Payment instance and associate with a Sale ?**



Bad Coupling



Good Coupling

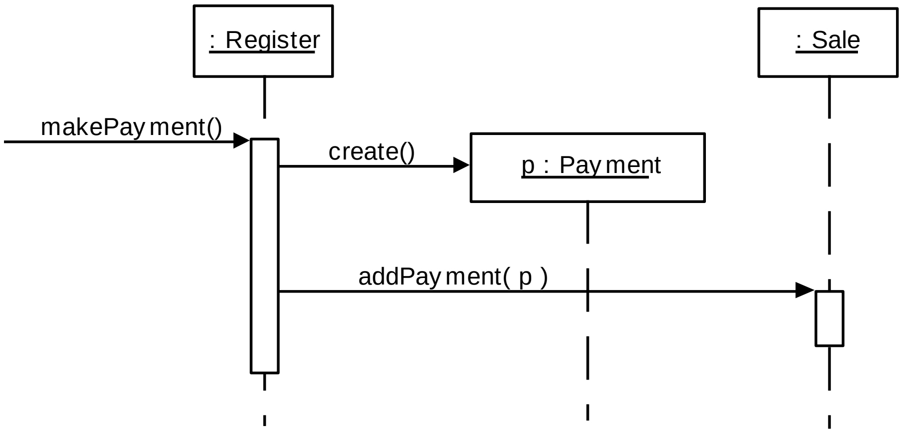
(5) High Cohesion

- **Problem :**
  - How to keep complexity manageable ?
  - Cohesion is a measure of how strongly related and focused the responsibilities of an element are.
- **Solution:**
  - Assign a responsibility so that cohesion remains high.
  - High Cohesion is an evaluative principle. Use this to evaluate alternatives.

Example of High Cohesion

- **Who should be responsible for creating a Payment instance and associate it with a Sale ?**

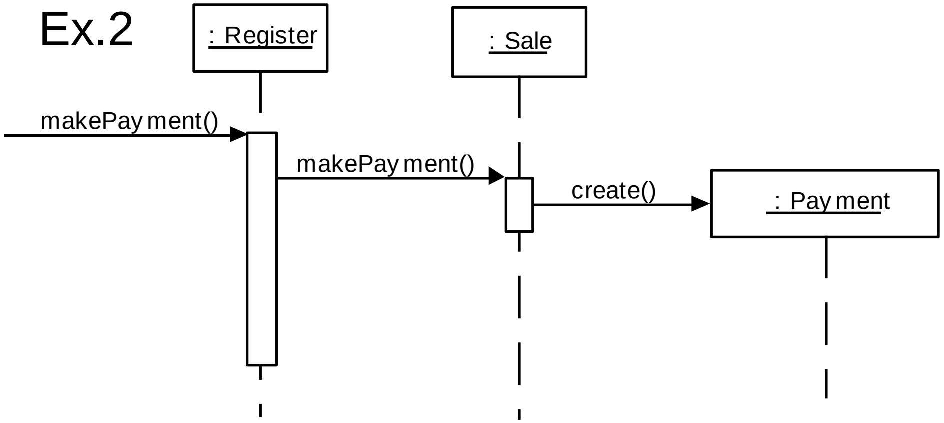
Ex.1



High Cohesion pattern suggest ex. 2

Creator pattern suggest ex. 1

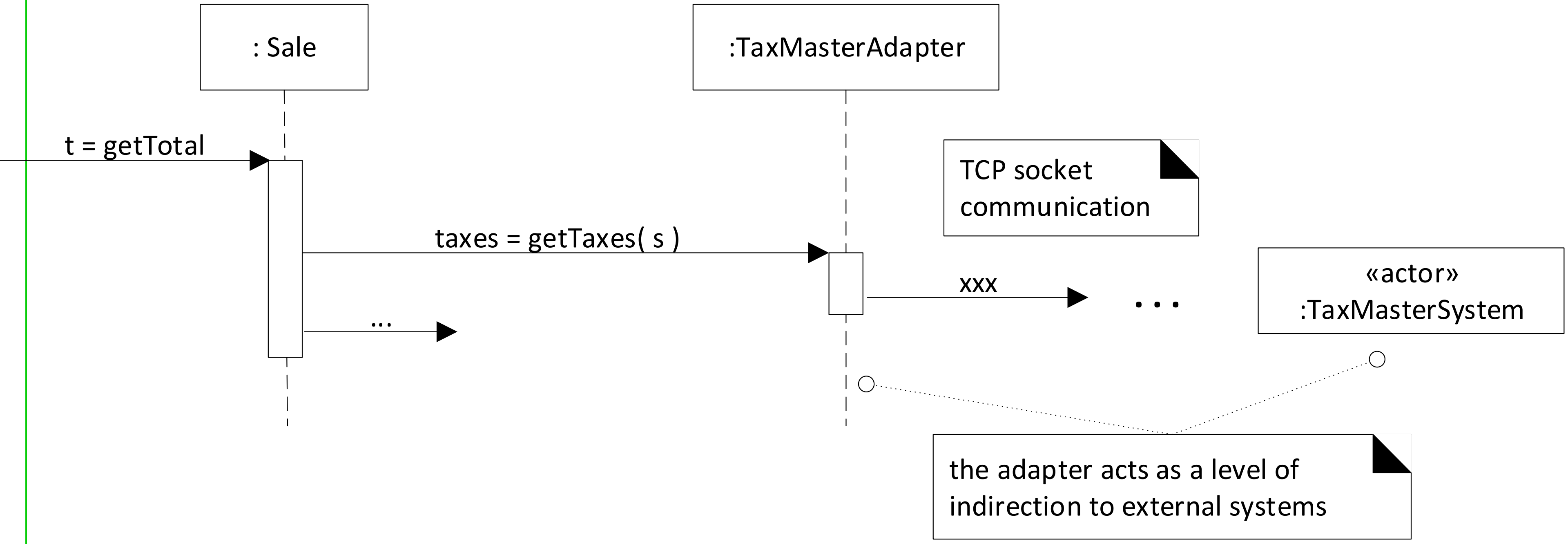
Ex.2



(6) Indirection

- **Problem:**
  - Where to assign a responsibility, to avoid direct coupling two (or more) things? How to decouple objects so that low coupling is supported and reuse potential remains higher?
- **Solution:**
  - Assign the responsibility to an intermediate object to mediate between other components or services so that they are not directly coupled. 将责任分配给中间对象，以避免直接耦合
- **The indirection pattern supports low coupling (and reuse potential) between two elements by assigning the responsibility of mediation between them to an intermediate object.**
- **An example of this is the introduction of a controller component for mediation between data (model) and its representation (view) in the model-view-controller pattern.**

(6) Indirection

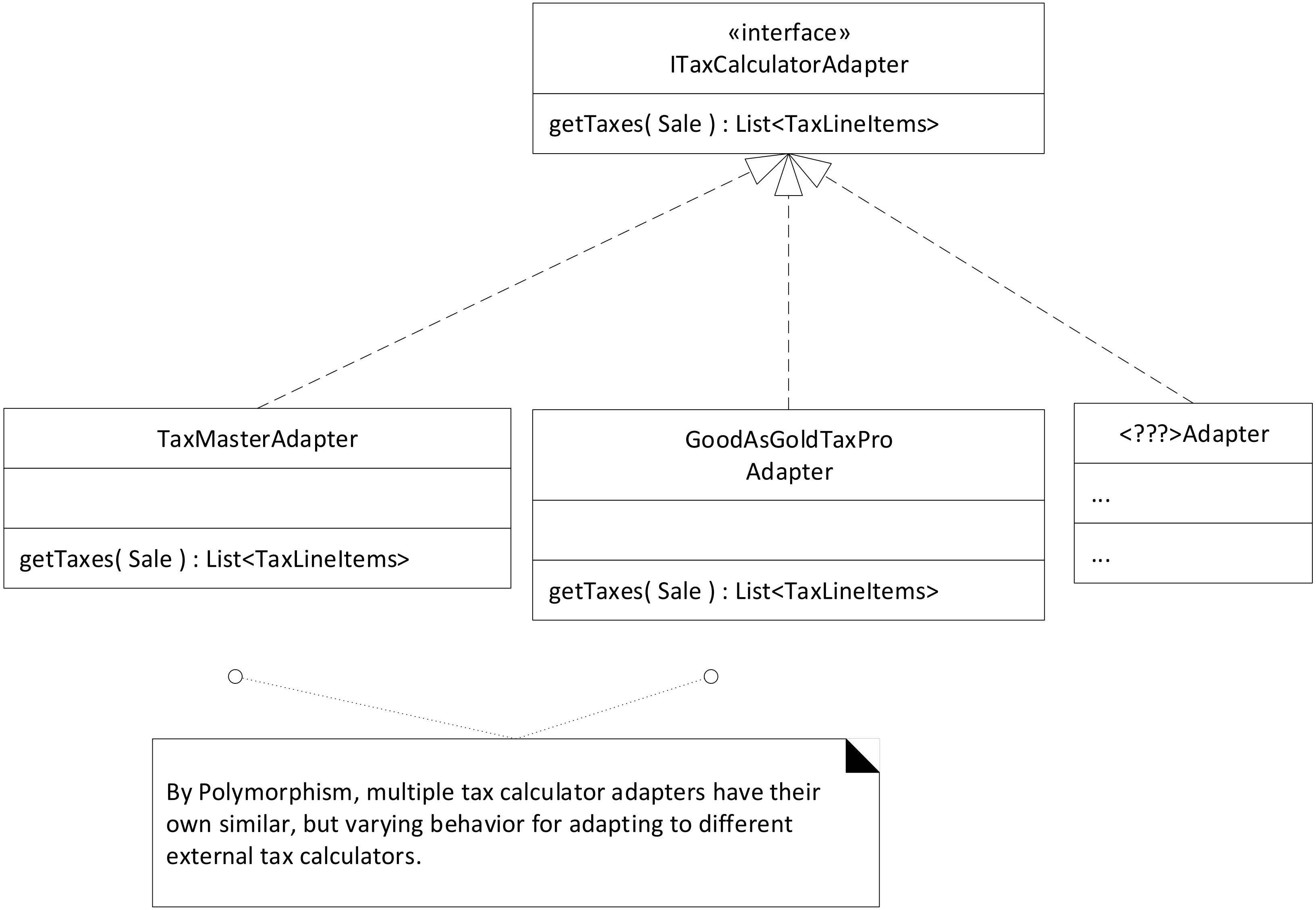


(7) Polymorphism

- **Problem:**
  - How handle alternatives based on type? How to create pluggable software components?
- **Solution:**
  - When related alternatives or behaviors vary by type(class), assign responsibility for the behavoior using polymorphic operations to the types for which the behavior varies.

- **According to polymorphism principle, responsibility of defining the variation of behaviors based on type is assigned to the type for which this variation happens.**
- **This is achieved using polymorphic operations.**
- **The user of the type should use polymorphic operations instead of explicit branching based on type.**

(7) Polymorphism



«interface»
ITaxCalculatorAdapter

getTaxes(Sale) : List<TaxLineItems>

TaxMasterAdapter

getTaxes(Sale) : List<TaxLineItems>

GoodAsGoldTaxPro
Adapter

getTaxes(Sale) : List<TaxLineItems>

<???>Adapter

...

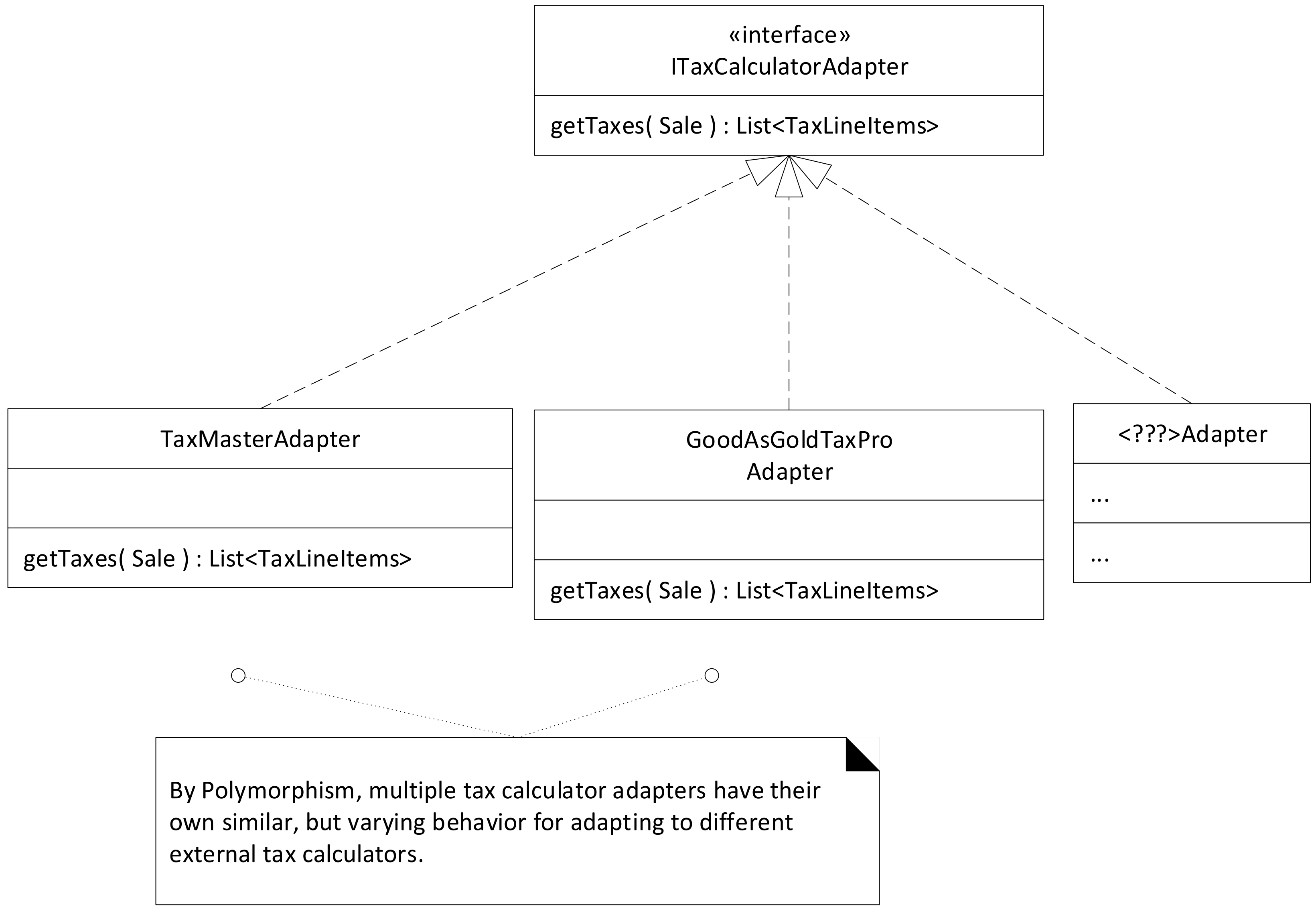
...

By Polymorphism, multiple tax calculator adapters have their own similar, but varying behavior for adapting to different external tax calculators.

(8) Protected variations 防止变异

- **Problem:**
  - How to design objects, subsystems, and systems so that the variations or instability in these elements does not have an undesirable impact on other elements?
- **Solution:**
  - Identify points of predicted variation or instability; 确定将会发生的变化
  - Assign responsibilities to create a stable interface around them 分配责任以创建稳定的接口
- **The protected variations pattern protects elements from the variations on other elements (objects, systems, subsystems) by wrapping the focus of instability with an interface and using polymorphism to create various implementations of this interface.**

(8) Protected variations 防止变异


«interface»
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Adapter
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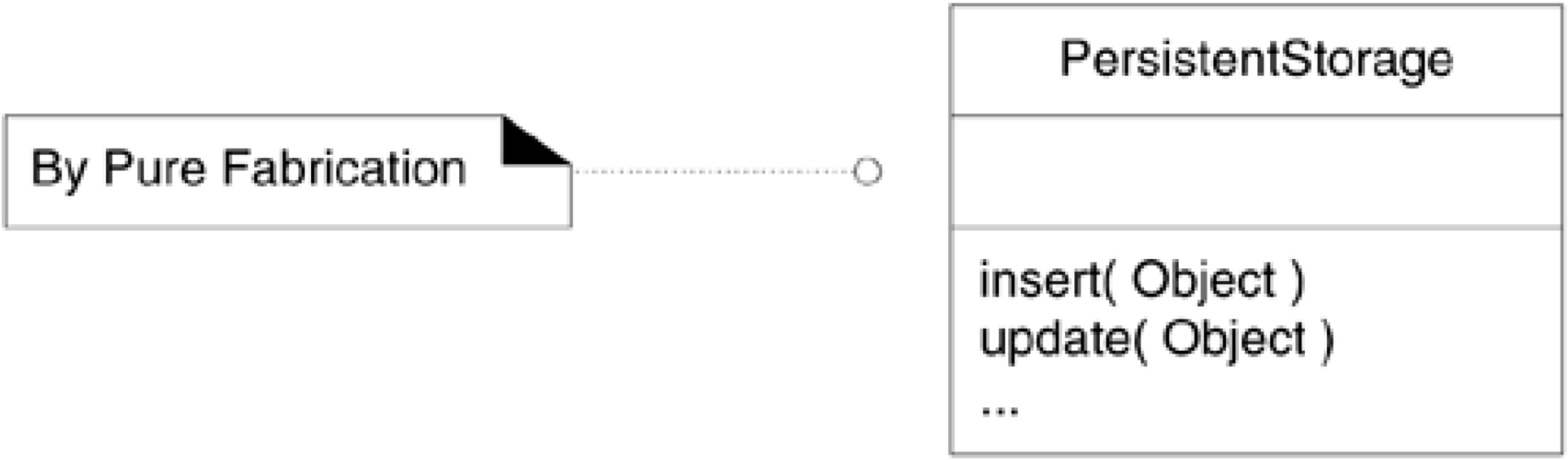
<???>Adapter
...
...

By Polymorphism, multiple tax calculator adapters have their own similar, but varying behavior for adapting to different external tax calculators.

(9) Pure fabrication 纯虚构

- **Problem:**
  - What object should have the responsibility, when you do not want to violate High Cohesion and Low Coupling, or other goals, but solutions offered by Expert(for example) are not appropriate？
- **Solution:**
  - Assign a highly cohesive set of responsibilities to an artificial or convenience class that does not represent a problem domain concept something made up, to support high cohesion, low coupling, and reuse.
- **A pure fabrication is a class that does not represent a concept in the problem domain, specially made up to achieve low coupling, high cohesion, and the reuse potential thereof derived (when a solution presented by the information expert pattern does not).**
- **This kind of class is called a "service" in domain-driven design.**

(9) Pure fabrication 纯虚构



Summary

The end

April 15, 2018