IT4490 - SOFTWARE DESIGN AND CONSTRUCTION

11. DESIGN PRINCIPLES

Nguyen Thi Thu Trang
trangntt@soict.hust.edu.vn

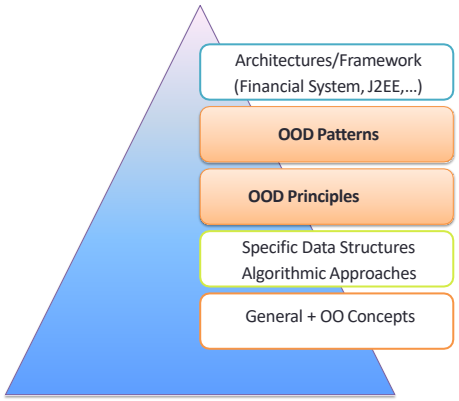
1

Content

1. How do you design?
2. Coupling and Cohesion
3. S.O.L.I.D. principles
4. Case study: Reminder program

2

Design levels



3

Key design concepts

General	OO Specific

• Cohesion
• Coupling
• Information hiding
  • Encapsulation
  • Creation
• Binding time
	• Behaviors follow data
	• Class vs. Interface Inheritance
	  • Class = implementation
	  • Interface = type
	• Inheritance / composition / delegation

4

What's Purpose Of Design?

- What's a design?
  - Express a idea to resolve a problem
  - Use for communications in the team members
- What's a good design?
  - Easy for Developing, Reading & Understanding
  - Easy for Communication
  - Easy for Extending (add new features)
  - Easy for Maintenance

5

How do you design?

- What principles guide you when you create a design?
- What considerations are important?
- When have you done enough design and can begin implementation?

•Take a piece of paper and write down two principles that guide you - considerations that are important or indicators that you have a good design.

6

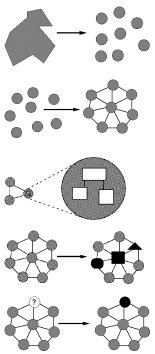
Modules

- A *module* is a relatively general term for a class or a type or any kind of design unit in software
- A *modular design* focuses on what modules are defined, what their specifications are, how they relate to each other, but not usually on the implementation of the modules themselves
- Overall, you've been given the modular design so far – and now you have to learn more about how to do the design

7

Ideals of modular software

- Decomposable – can be broken down into modules to reduce complexity and allow teamwork
- Composable – "Having divided to conquer, we must reunite to rule [M. Jackson]."
- Understandable – one module can be examined, reasoned about, developed, etc. in isolation
- Continuity – a small change in the requirements should affect a small number of modules
- Isolation – an error in one module should be as contained as possible



8

Content

1. How do you design?
2. Coupling and Cohesion
3. S.O.L.I.D. principles
4. Case study: Reminder program

9

Two general design issues

- *Cohesion* – why are sub-modules (like methods) placed in the same module? Usually to collectively form an ADT
- *Coupling* – what is the dependence between modules? Reducing the dependences (which come in many forms) is desirable

10

Cohesion

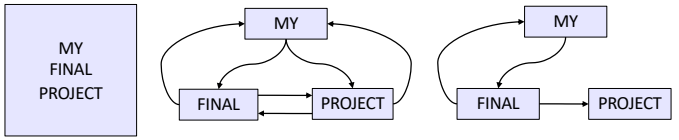
- The most common reason to put elements – data and behavior – together is to form an ADT
  - There are, at least historically, other reasons to place elements together – for example, for performance reasons it was sometimes good to place together all code to be run upon initialization of a program
- The common design objective of separation of concerns suggests a module should address a single set of concerns Example considerations
  - Should Item/DiscountItem know about added discount for purchasing 20+ items? Should ShoppingCart know about bulk pricing?
  - Should BinarySearch know the type of the objects it is sorting?
- This kind of questions help make more effective cohesion decisions

11

Coupling

Roughly, the more coupled k modules are, the more one needs to think of them as a single, larger module

- How are modules dependent on one another?
  - Statically (in the code)? Dynamically (at run-time)? And more
  - Ideally, split design into parts that don't interact much



An application | *A poor decomposition (parts strongly coupled)* | *A better decomposition (parts weakly coupled)*

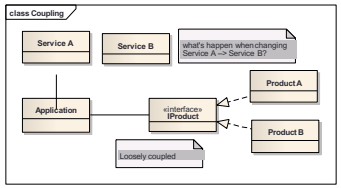
- An artist's rendition – to really assess coupling one needs to know what the arrows are, etc.

12

Cohesion and Coupling

- Coupling

Coupling or ***Dependency*** is the degree to which each program module relies on each one of the other modules.



- Cohesion

Cohesion refers to the degree to which the elements of a module belong together. ***Cohesion*** is a measure of how strongly-related or focused the responsibilities of a single module are.

13

What's Purpose Of Design?

- What's a design?
  - Express a idea to resolve a problem.
  - Use for communications in the team members.
- What's a good design?
- "Cohesion and Coupling deal with the quality of an OO design"
  - Easy for Developing, reading & understanding.
  - Easy for Communication.
  - Easy for Extending (add new features)
  - Easy for Maintenance.

➔ "Loose coupling and high cohesion" idea!!!

14

Different kinds of dependences

- Aggregation – "is part of" is a field that is a sub-part
  - Ex: A car has an engine
- Composition – "is entirely made of" has the parts live and die with the whole
  - Ex: A book has pages (but perhaps the book cannot exist without the pages, and the pages cannot exist without the book)
- Subtyping – "is-a" is for substitutability
- Invokes – "executes" is for having a computation performed
- In other words, there are lots of different kinds of arrows (dependences) and clarifying them is crucial

15

Law of Demeter

Karl Lieberherr ⓘ and colleagues

- Law of Demeter: An object should know as little as possible about the internal structure of other objects with which it interacts – a question of coupling
- Or… "only talk to your immediate friends"
- Closely related to representation exposure and (im)mutability
- Bad example – too-tight chain of coupling between classes

```
general.getColonel().getMajor(m).getCaptain(cap)
    .getSergeant(ser).getPrivate(name).digFoxHole();
```

- Better example

```
general.superviseFoxHole(m, cap, ser, name);
```

16

17

An object should only send messages to … (More Demeter)

- itself (`this`)
- its instance variables
- its method's parameters
- any object it creates
- any object returned by a call to one of `this`'s methods
- any objects in a collection of the above

Guidelines: not strict rules! But thinking about them will generally help you produce better designs

- notably absent: objects returned by messages sent to other objects

17

18

Coupling is the path to the dark side

- Coupling leads to complexity
- Complexity leads to confusion
- Confusion leads to suffering

- Once you start down the dark path, forever will it dominate your destiny, consume you it will

18

19

God classes

- *God class*: a class that hoards too much of the data or functionality of a system
  - Poor cohesion – little thought about why all of the elements are placed together
  - Only reduces coupling by collapsing multiple modules into one (and thus reducing the dependences between the modules to dependences within a module)

- A god class is an example of an *anti-pattern* – it is a known bad way of doing things

19

20

Content

1. How do you design?
2. Coupling and Cohesion
3. S.O.L.I.D. principles
4. Case study: Reminder program

20

Principles of OO Class Design

- SRP: The Single Responsibility Principle
- OCP: The Open Closed Principle
- LSP: The Liskov Substitution Principle
- ISP: The Interface Segregation Principle
- DIP: The Dependency Inversion Principle

21

Principles of OO Class Design

SRP: The Single Responsibility Principle

"There should never be more than one reason for a class to change"

Or

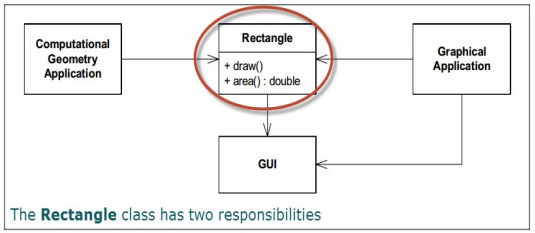
"A class should have one, and only one type of responsibility."

22

Principles of OO Class Design

SRP: The Single Responsibility Principle (cont)

- Two applications are using this Rectangle class:
  - Computational Geometry Application uses this class to calculate the Area
  - Graphical Application uses this class to draw a Rectangle in the UI

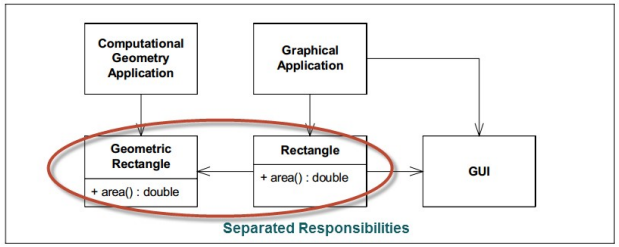


23

Principles of OO Class Design

SRP: The Single Responsibility Principle (cont)

- A better design is to separate the two responsibilities into two completely different classes



- Why is it important to separate these two responsibilities into separate classes?

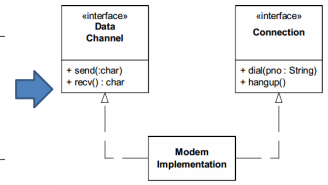
24

Principles of OO Class Design
SRP: The Single Responsibility Principle (cont)

- What is a Responsibility?
  - A reason for change
- "Modem" sample
  - dial & hangup functions for managing connection
  - send & recv functions for data communication

➔ Should separate into 2 repositories!

```
Modem.java -- SRP Violation
interface Modem
{
  public void dial(String pno);
  public void hangup();
  public void send(char c);
  public char recv();
}
```



Separated Modem Interface

25

Principles of OO Class Design
OCP: The Open Closed Principle

"Software entities(classes, modules, functions, etc.) should be open for extension, but closed for modification."

Bertrand Meyer, 1988

Or

"You should be able to extend a classes behavior, without modifying code"

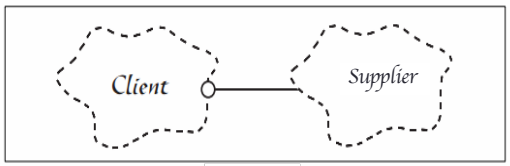
- "Open for Extension"
  - The behavior of the module/class can be extended
  - The module behave in new and different ways as the requirements changes, or to meet the needs of new aplications
- "Closed for Modification"
  - The source code of such a module is inviolate
  - No one is allowed to make source code changes to it

26

Principles of OO Class Design
OCP: The Open Closed Principle (cont)

- Client & Supplier classes are concrete
- If the Supplier implementation/class is changed, Client also needs change.

➔ How to resolve this problem?



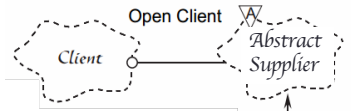
Closed Client

27

Principles of OO Class Design
OCP: The Open Closed Principle (cont)

- Change to support Open-Closed Principle.

➔ Abstraction is the key.



- The Concrete Supplier class implements the Abstract Supplier class / Supplier Interface.
  - The Supplier implementation is changed,
  - the Client is likely not to require any change.

➔ The Abstract Supplier class here is closed for modification and the Concrete class implementations here are Open for extension.

21

28

Principles of OO Class Design
LSP: The Liskov Substitution Principle

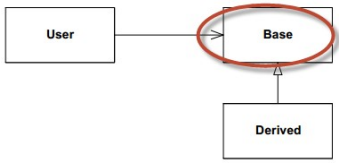
- *"Functions that use pointers or references to base classes must be able to use objects of derived classes without knowing it."*
- Or

"Subclasses should be substitutable for their base classes."

User, Based, Derived, example.

```
void User(Base& b);

Derived d;
User(d);
```



22

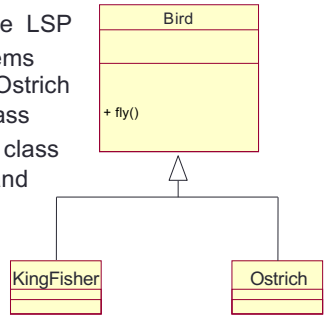
29

Principles of OO Class Design
LSP: The Liskov Substitution Principle (cont)

- Ostrich is a Bird (definitely!!!)
- Can it fly? No! => Violates the LSP

➔Even if in real world this seems natural, in the class design, Ostrich should not inherit the Bird class

➔There should be a separate class for birds that can't really fly and Ostrich inherits that.



30

Principles of OO Class Design
LSP: The Liskov Substitution Principle (cont)

- "Inheritance" ~ "is a" relationship
  - But, easy to get carried away and end up in wrong design with bad inheritance.

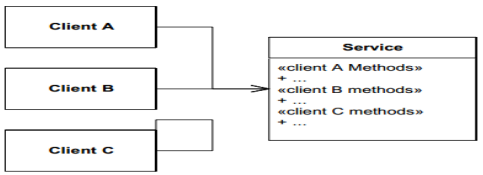
  ➔ The LSP is a way of ensuring that inheritance is used correctly
- Why The LSP is so important? If not LSP,
  - Class hierarchy would be a **mess** and if subclass instance was passed as parameter to methods method, strange behavior might occur.
  - Unit tests for the Base classes would never succeed for the subclass.

  ➔ LSP is just an extension of Open-Close Principle!!!

31

Principles of OO Class Design
ISP: The Interface Segregation Principle

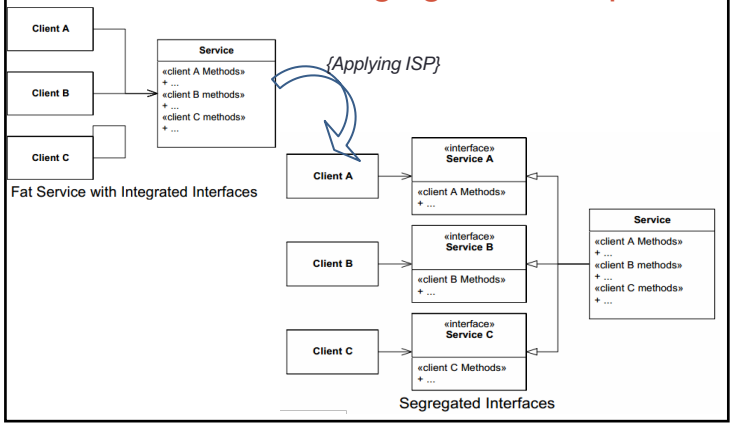
- *"Client should not be forced to depend upon interface that they do not use."*
- *Or*
- *"Many client specific interfaces are better than one general purpose interface."*



Fat Service with Integrated Interfaces

32

Principles of OO Class Design
ISP: The Interface Segregation Principle



33

Principles of OO Class Design
ISP: The Interface Segregation Principle (cont.)

- Interfaces with too many methods are less re-usable.
- Such "fat interfaces“ with additional useless methods lead to inadvertent coupling between classes.
- Doing this also introduce unnecessary complexity and reduces maintainability or robustness in the system.

➔ The ISP ensures that, Interfaces are developed so that, each of them have their own responsibility and thus they are re-usable.

34

Principles of OO Class Design
DIP: The Dependency Inversion Principle

“High level modules should not depend upon low level modules. Both should depend upon abstractions”

Or

“Abstractions should not depend upon details. Details should depend upon abstraction.”

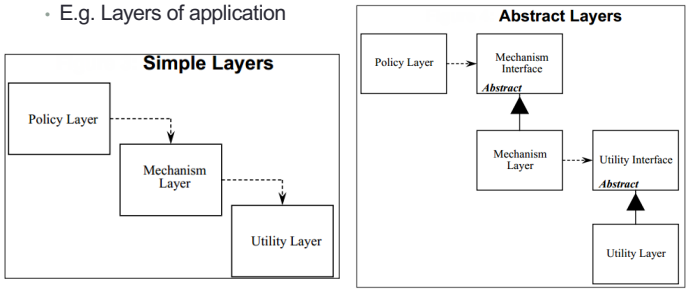
Or

“Depend upon Abstractions. Do not depend upon concretions.”

35

Principles of OO Class Design
DIP: The Dependency Inversion Principle

- Strategy of depending upon interfaces or abstract functions and classes, rather than upon concrete functions and classes.
  - A well designed object-oriented application.
  - E.g. Layers of application



36

Content

1. How do you design?
2. Coupling and Cohesion
3. S.O.L.I.D. principles
4. Case study: Reminder program

37

Design exercise

- Write a typing break reminder program
  - Offer the hard-working user occasional reminders of the health issues, and encourage the user to take a break from typing
- Naive design
  - Make a method to display messages and offer exercises
  - Make a loop to call that method from time to time

(Let's ignore multi-threaded solutions for this discussion)

38

TimeToStretch suggests exercises

```
public class TimeToStretch {
  public void run() {
    System.out.println("Stop typing!");
    suggestExercise();
  }
  public void suggestExercise() {
  ...
  }
}
```

39

Timer calls run() periodically

```
public class Timer {
  private TimeToStretch tts = new TimeToStretch();
  public void start() {
    while (true) {
      ...
      if (enoughTimeHasPassed) {
        tts.run();
      }
      ...
    }
  }
}
```

40

41

Main class puts it together

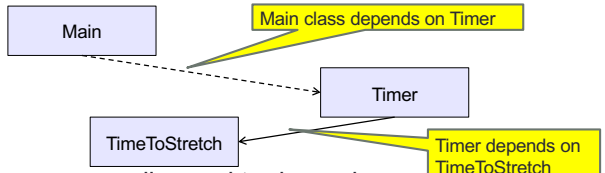
```
class Main {
  public static void main(String[] args) {
    Timer t = new Timer();
    t.start();
  }
}
```

41

42

Module dependency diagram

- An arrow in a module dependency diagram indicates "depends on" or "knows about" – simplistically, "any name mentioned in the source code"



- Does **`Timer`** really need to depend on **`TimeToStretch`**?
- Is Timer re-usable in a new context?

42

43

Decoupling

- **`Timer`** needs to call the **`run`** method
  - **`Timer`** doesn't need to know what the **`run`** method does
- Weaken the dependency of **`Timer`** on **`TimeToStretch`**
- Introduce a weaker specification, in the form of an interface or abstract class

```
public abstract class TimerTask {
    public abstract void run();
}
```

- **`Timer`** only needs to know that something (e.g., **`TimeToStretch`**) meets the **`TimerTask`** specification

43

44

TimeToStretch (version 2)

```
public class TimeToStretch extends TimerTask {
  public void run() {
    System.out.println("Stop typing!");
    suggestExercise();
  }

  public void suggestExercise() {
    ...
  }
}
```

44

45

Timer v2

```
public class Timer {
  private TimerTask task;
  public Timer(TimerTask task) { this.task = task; }
  public void setTask(TimerTask task){this.task = task;}
  public void start() {
    while (true) {
      ...
      if (enoughTime)
            task.run();
    }
  }
}
```

- Main creates the `TimeToStretch` object and passes it to `Timer`

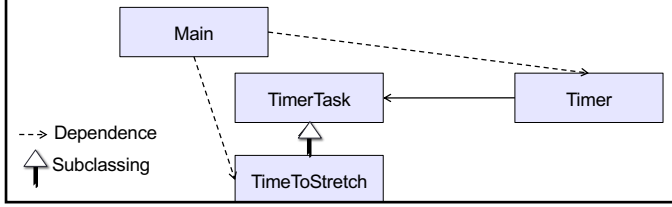
```
Timer t = new Timer(new TimeToStretch());
t.start();
t.setTask(new TimeToSave());
t.start();
```

45

46

Module dependency diagram

- `Main` still depends on `Timer` (is this necessary?)
- `Main` depends on the constructor for `TimeToStretch`
- `Timer` depends on `TimerTask`, not `TimeToStretch`
  - Unaffected by implementation details of `TimeToStretch`
  - Now `Timer` is much easier to reuse

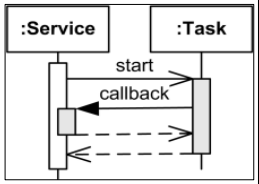


46

47

callbacks

- **`TimeToStretch`** creates a **`Timer`**, and passes in a reference to itself so the **`Timer`** can call it back
- This is a *callback* – a method call from a module to a client that notifies about some condition
- Use a callback to invert a dependency
  - Inverted dependency: `TimeToStretch` depends on `Timer` (not vice versa)
  - Side benefit: `Main` does not depend on `Timer`



A synchronous callback.
Time increases downward.
Solid lines: calls
Dotted lines: returns

47

49

TimeToStretch v3

```
public class TimeToStretch extends TimerTask {
    private Timer timer;
    public TimeToStretch() {
        timer = new Timer(this);
    }
    public void start() {
        timer.start();
    }
    public void run() {
        System.out.println("Stop typing!");
        suggestExercise();
    }
    ...
}
```

Register interest with the timer

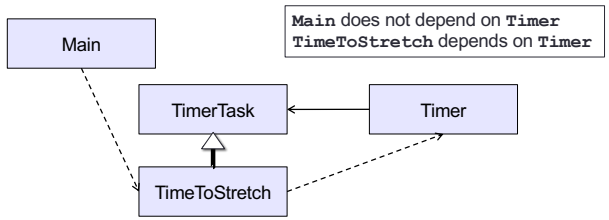
Callback entry point

49

50

Main v3

- `TimeToStretch tts = new TimeToStretch();`
  `tts.start();`
- Use a callback to invert a dependency
- This diagram shows the inversion of the dependency between `Timer` and `TimeToStretch` (compared to v1)



50

51

How do we design classes?

- One common approach to class identification is to consider the specifications
- In particular, it is often the case that
  - *nouns* are potential classes, objects, fields
  - *verbs* are potential methods or responsibilities of a class

51

52

Design exercise

- Suppose we are writing a birthday-reminder application that tracks a set of people and their birthdays, providing reminders of whose birthdays are on a given day
- What classes are we likely to want to have? Why?

Class shout-out about classes

52

53

More detail for those classes

- What fields do they have?
- What constructors do they have?
- What methods do they provide?
- What invariants should we guarantee?

In small groups, ~5 minutes

53