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Chapter 5: Reusability-Oriented Software Construction Approaches

5.2 Construction for Reuse

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Outline

- **Designing reusable classes**
  - Inheritance and overriding
  - Behavioral subtyping and overloading
  - Parametric polymorphism and generic programming
  - Composition and delegation
- **Designing system-level reusable libraries and frameworks**
  - API and Library
  - Framework
  - Java Collections Framework (an example)

1 Designing reusable classes

(1) Inheritance and overriding

see 3.4

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(2) Polymorphism, subtyping and overloading

(a) Three Types of Polymorphism

Three Types of Polymorphism (多态)

- **Polymorphism** is the provision of a single interface to entities of different types or the use of a single symbol to represent multiple different types **多态性是指为不同类型的实体提供一个接口，或者使用一个符号来表示多个不同的类型。**
  - **Ad hoc polymorphism**: when a function denotes different and potentially heterogeneous(异构的) implementations depending on a limited range of individually specified types and combinations. Ad hoc polymorphism is supported in many languages using **function overloading**. **一个函数可以有多个同名的实现(方法重载)**
  - **Parametric polymorphism 参数多态性**: when code is written without mention of any specific type and thus can be used transparently with any number of new types. In the object-oriented programming community, this is often known as generics or **generic programming**. **一个类型名字可以代表多个类型(泛型编程)**
  - **Subtyping** (also called **subtype polymorphism** or **inclusion polymorphism**): when a name denotes instances of many different classes related by some common superclass **一个变量名字可以代表多个类的实例(子类型)**

(b) Ad hoc polymorphism and Overloading **see 3.4**

(c) Parametric polymorphism and generic programming **see3.4**

(d) Subtyping Polymorphism

see 3.4

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(e) Behavioral subtyping and Liskov Substitution Principle (LSP)

Behavioral subtyping

- **Let q(x) be a property provable about objects x of type T. Then q(y) should be provable for objects y of type S where S is a subtype of T.**

— —Barbara Liskov

- **Compiler-enforced rules in Java:**
  - Subtypes can add, but not remove methods
  - Concrete class must implement all undefined methods
  - Overriding method must return same type or subtype
  - Overriding method must accept the same parameter types
  - Overriding method may not throw additional exceptions
- **Also applies to specified behavior:**
  - Same or stronger invariants
  - Same or stronger postconditions for all methods
  - Same or weaker preconditions for all methods

Liskov Substitution Principle (LSP)

Behavioral subtyping (LSP)

- **Subclass fulfills the same invariants (and additional ones)**
- **Overridden method has the same pre and postconditions**

```
abstract class Vehicle {
        int speed, limit;

        //@ invariant speed < limit;

        //@ requires speed != 0;
        //@ ensures speed < \old(speed)
        void brake();
}
```

```
class Car extends Vehicle {
        int fuel;
        boolean engineOn;
        //@ invariant speed < limit;
        //@ invariant fuel >= 0;

        //@ requires fuel > 0 && !engineOn;
        //@ ensures engineOn;
        void start() { … }

        void accelerate() { … }

        //@ requires speed != 0;
        //@ ensures speed < \old(speed)
        void brake() { … }
}
```

Behavioral subtyping (LSP)

- **Subclass fulfills the same invariants (and additional ones)**
- **Overridden method `start` has weaker precondition**
- **Overridden method `brake` has stronger postcondition**

```
class Car extends Vehicle {
        int fuel;
        boolean engineOn;
        //@ invariant fuel >= 0;

        //@ requires fuel > 0 && !engineOn;
        //@ ensures engineOn;
        void start() { … }

        void accelerate() { … }

        //@ requires speed != 0;
        //@ ensures speed < old(speed)
        void brake() { … }
}
```

```
class Hybrid extends Car {
        int charge;
        //@ invariant charge >= 0;

        //@ requires (charge > 0 || fuel > 0)
                        && !engineOn;
        //@ ensures engineOn;
        void start() { … }

        void accelerate() { … }

        //@ requires speed != 0;
        //@ ensures speed < \old(speed)
        //@ ensures charge > \old(charge)
        void brake() { … }
}
```

Behavioral subtyping (LSP)

- **How about these two classes? Is LSP satisfied?**

```
class Rectangle {
        int h, w;

        Rectangle(int h, int w) {
                this.h=h; this.w=w;
        }

        //methods
}
```

```
class Square extends Rectangle {
        Square(int w) {
                super(w, w);
        }
}
```

```
class Rectangle {
        //@ invariant h>0 && w>0;
        int h, w;

        Rectangle(int h, int w) {
                this.h=h; this.w=w;
        }

        //methods
}
```

```
class Square extends Rectangle {
        //@ invariant h>0 && w>0;
        //@ invariant h==w;
        Square(int w) {
                super(w, w);
        }
}
```

Behavioral subtyping (LSP)

- **How about these two classes? Is LSP satisfied?**

```
class Rectangle {
        //@ invariant h>0 && w>0;
        int h, w;

        Rectangle(int h, int w) {
            this.h=h; this.w=w;
        }

        //@ requires factor > 0;
        void scale(int factor) {
            w=w*factor;
            h=h*factor;
        }
}
```

```
class Square extends Rectangle {
        //@ invariant h>0 && w>0;
        //@ invariant h==w;
        Square(int w) {
            super(w, w);
        }
}
```

Behavioral subtyping (LSP)

- **How about these two classes? Is LSP satisfied?**

```
class Rectangle {
        //@ invariant h>0 && w>0;
        int h, w;

        Rectangle(int h, int w) {
                this.h=h; this.w=w;
        }

        //@ requires factor > 0;
        void scale(int factor) {
                w=w*factor;
                h=h*factor;
        }
        //@ requires neww > 0;
        void setWidth(int neww) {
                w=neww;
        }
}
```

```
class Square extends Rectangle {
        //@ invariant h>0 && w>0;
        //@ invariant h==w;
        Square(int w) {
                super(w, w);
        }
}
```

```
class GraphicProgram {
   void scaleW(Rectangle r, int factor) {
      r.setWidth(r.getWidth() * factor);
   }
}
```

Invalidates stronger invariant (w==h) in subclass

Variance

- **Variance** refers to how subtyping between more complex types relates to subtyping between their components. 型变是指当子类型关系出现在更加复杂类型中时，如何处理新类型中的子类型关系
  - E.g., Cat extends Animal, the type Cat is a subtype of Animal.
  - How should List<Cat> relate to List<Animal>?
  - Or how should a function returning Cat relate to a function returning Animal?

- **Three types of variance**
  - **Covariant(协变):** Subtyping is preserved. If List<Cat> is a subtype of List<Animal>. 保持子类型关系
  - **Contravariant(逆变):** Subtyping is reversed. If List<Animal> is a subtype of List<Cat>. 反转了子类型关系
  - **Invariant(不变):** Neither List<Cat> nor List<Animal> is a subtype of the other. 没有子类型关系

Variance

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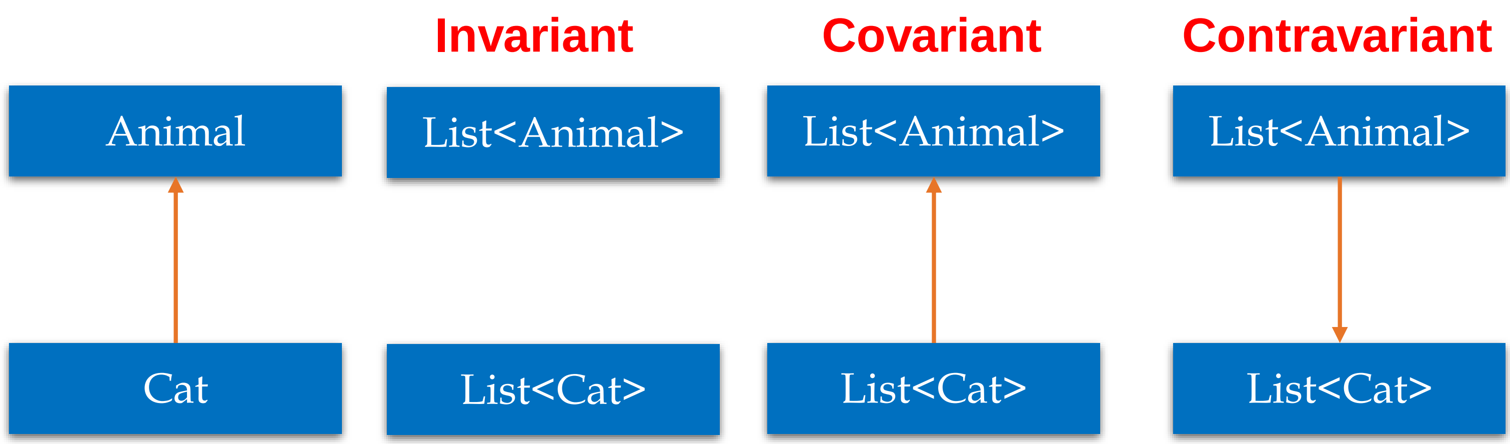
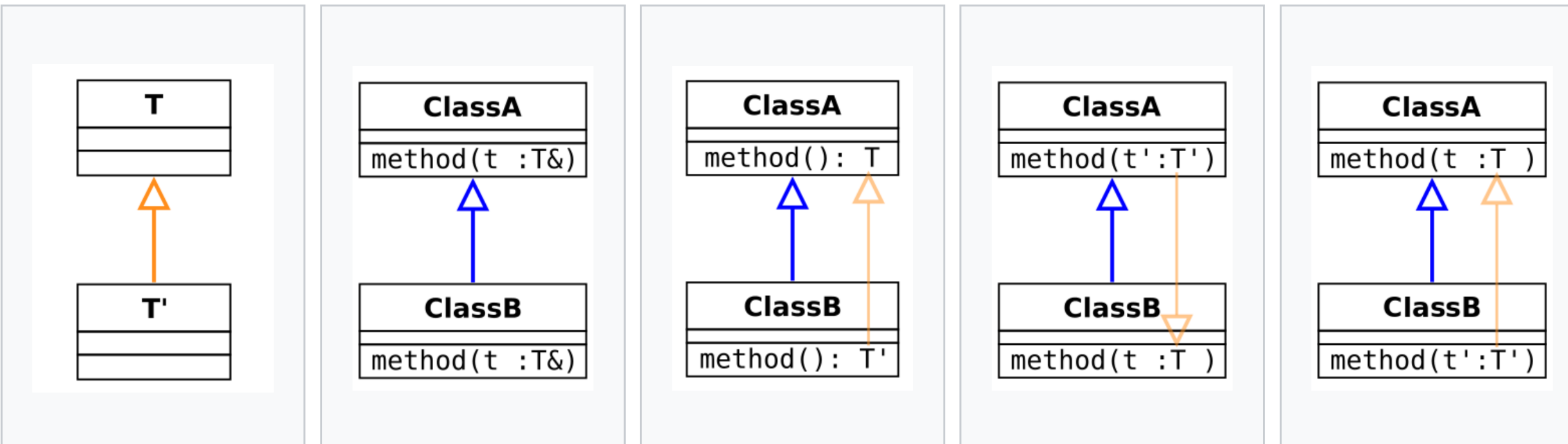


Variance in method overriding



Subtyping of the argument/return type of the method.

Invariance**.** The signature of the overriding method is unchanged.

Covariant return type**.** The subtyping relation is in the same direction as the relation between ClassA and ClassB.

Contravariant argument type. The subtyping relation is in the opposite direction to the relation between ClassA and ClassB.

Covariant argument type. Not type safe.

https://en.wikipedia.org/wiki/Covariance_and_contravariance_(computer_science)

Variance in method overriding

- **Covariant method return type**
  - In a language which allows **covariant return types**, a derived class can override the getAnimalForAdoption method to return a more specific type
  - Java(from 1.5) and C++ support covariant return types

```
class Animal{ }
class Cat extends Animal{}

public class AnimalShelter {
    Animal getAnimalForAdoption() { // ...}

    void putAnimal(Animal animal) { // ...}
}

class CatShelter extends AnimalShelter {

    Cat getAnimalForAdoption() {  return new Cat(); }

    void putAnimal(Object animal) { // ...}
}
```

Variance in method overriding

- **Contravariant method argument type**
  - Similarly, it is type safe to allow an overriding method to accept a more general argument than the method in the base class
  - Not many object-oriented languages actually allow this. C++ and Java would interpret this as an unrelated method with an **overloaded name**.

```
class Animal{ }
class Cat extends Animal{}

public class AnimalShelter {
    Animal getAnimalForAdoption() { // ...}

    void putAnimal(Animal animal) { // ...}
}

class CatShelter extends AnimalShelter {

    Cat getAnimalForAdoption() {  return new Cat(); }

    void putAnimal(Object animal) { // ...}
}
```

Variance in generics

- **Generics are type invariant in Java** **Java中的泛型是不"型变"的**
  - `ArrayList<Cat>` is a subtype of `List<Cat>`
  - `List<Cat>` is not a subtype of `List<Animal>`
- **Wildcards(通配符)**
  - e.g. `List<?>` or `List<? extends Animal>` or `List<? super Animal>`
- **Generic type info is erased in running-time(i.e. compile-time only)**
  - Cannot use `instanceof` to check generic type
- **Covariant in generics:**
  - `List<Cat>` is a subtype of `List<? extends Animal>`
- **Contravariant in generics:**
  - `List<Animal>` is a subtype of `List<? super Cat>`

Type Erasure

- **The virtual machine does not have objects of generic types — all objects belong to ordinary classes. 虚拟机中没有泛型类型对象-所有对象都属于普通类!**
- **Generic type info is erased in running-time(i.e. compile-time only) 泛型信息只存在于编译阶段，在运行时会被"擦除"**
  - Whenever you define a generic type, a corresponding *raw* type is automatically provided. The name of the raw type is simply the name of the generic type, with the type parameters removed. **定义泛型类型时，会自动提供一个对应的原始类型(非泛型类型)，原始类型的名字就是去掉类型参数后的泛型类型名。**
  - The type variables are *erased* and replaced by their bounding types (or Object for variables without bounds) **类型变量会被擦除，替换为限定类型，如果没有限定类型则为Object类型。**

Type Erasure

```
public class Pair<T>
{
    private T first;
    private T second;
    public Pair() { first = null; second = null; }
    public Pair(T first, T second)
        { this.first = first; this.second = second; }
    public T getFirst() { return first; }
    public T getSecond() { return second; }
    public void setFirst(T newValue) { first = newValue; }
    public void setSecond(T newValue) { second = newValue; }
}
```

After erasure (to Object)

```
public class Pair
{
    private Object first;
    private Object second;
    public Pair(Object first, Object second)
    { this.first = first; this.second = second;}
    public Object getFirst() { return first; }
    public Object getSecond() { return second; }
    public void setFirst(Object newValue) { first = newValue; }
    public void setSecond(Object newValue) { second = newValue; }
}
```

Type Erasure

```
public class Interval<T extends Comparable & Serializable> implements Serializable
{
    private T lower;
    private T upper;
    . . .
    public Interval(T first, T second)
    {
        if (first.compareTo(second) <= 0) { lower = first; upper = second; }
        else { lower = second; upper = first; } //此处因为限定了T的具体类型，所以可以调
                                                 用类型相关的具体方法
    }
}
```

After erasure (to bounding type)

```
public class Interval implements Serializable
{
    private Comparable lower;
    private Comparable upper;
    . . .
    public Interval(Comparable first, Comparable second) { . . . }
}
```

Runtime Type Inquiry Only Works with Raw Types

- **Runtime Type Inquiry Only Works with Raw Types 运行时类型查询只适用于原始类型**

```
if (a instanceof Pair<String>) // Error
if (a instanceof Pair<T>) // Error

Pair<String> stringPair = . . .;
Pair<Employee> employeePair = . . .;
if (stringPair.getClass() == employeePair.getClass())
  {}// they are equal
```

Subtype in generics

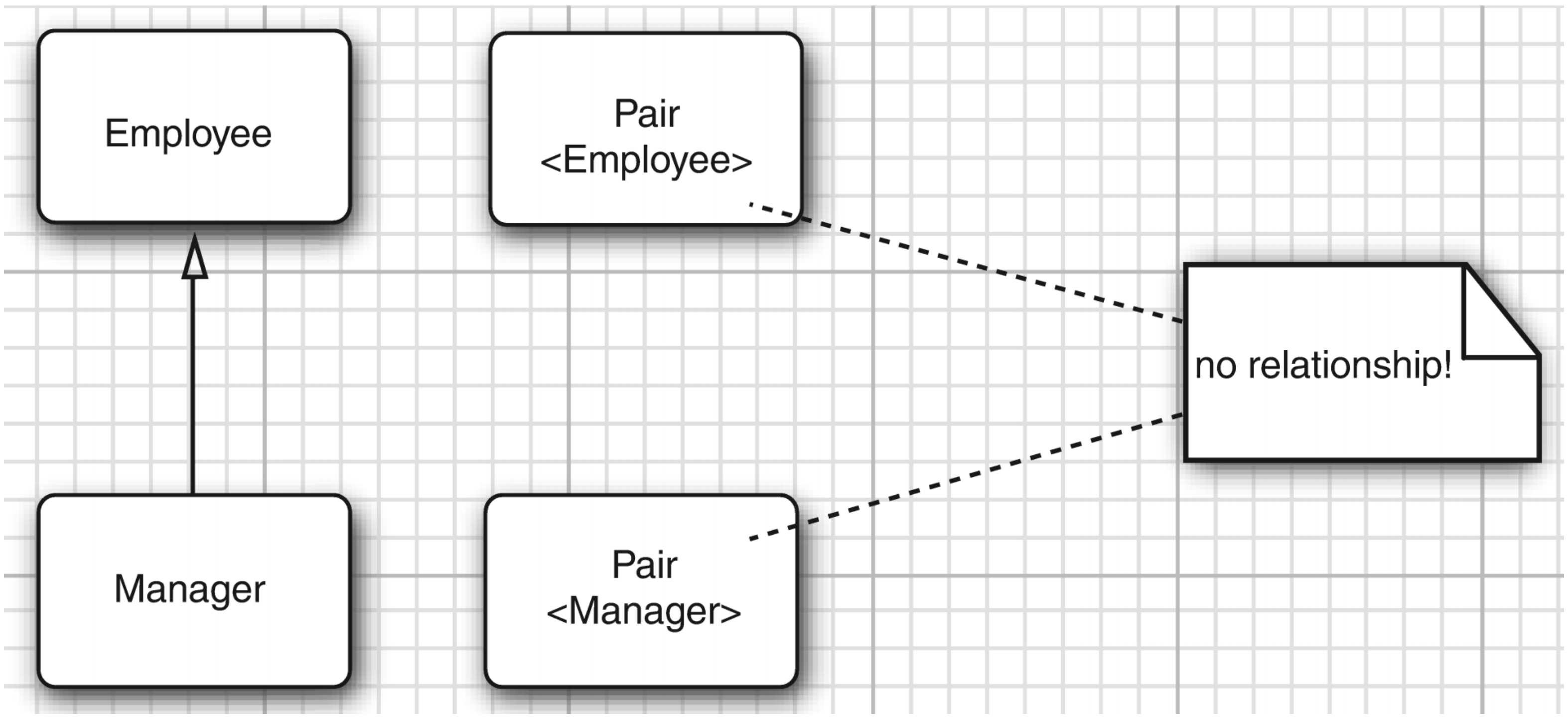
- **Generics are type invariant in Java** **Java中的泛型是不“型变”的**
  - `ArrayList<Cat>` is a subtype of `List<Cat>`
  - `List<Cat>` is not a subtype of `List<Animal>`
- **E.g., Manager is subtype of Employee, but Pair<Manager> is not a subtype of Pair<Employee>**

```
Pair<Manager> managerBuddies = new Pair<>(ceo, cfo);

// illegal, but suppose it wasn't
Pair<Employee> employeeBuddies = managerBuddies;
// legal
employeeBuddies.setFirst(lowlyEmployee);
```

  - But employeeBuddies and managerBuddies refer to the *same object*. We now managed to pair up the cfo with a lowly employee, which should not be possible for a Pair<Manager>. **employeeBuddies和managerBuddies现在指向了同一个对象，可以将cfo同普通员工分为一组，会出现错误（如工资等级设置等），因此第二行代码是不允许的。**

Subtype in generics



Variance in generics

- **Covariant in generics:**
  - `List<Cat>` is a subtype of `List<? extends Animal>`

```
List<Cat> objs = new ArrayList<>();
objs.add(new Cat());
objs.add(new WhiteCat());
List<? extends Animal> animals = objs;

animals.add(new Cat());     //compile error
animals.add(new Animal());  //compile error
animals.add(new Object()); //compile error
animals.add(null);          //succeed, but it is meaningless.

Animal animal = animals.get(0); //succeed!
```

  - 对于类型 List<? extends Animal>,调用一个返回Animal类型(或子类型)的方法(如: T get(int pos))是安全的, 因为compiler知道这个List中的任何对象至少具有Animal类型(或子类型),可以完成类型转换。
  - 但调用类似add(E e)的方法则不安全,类型擦除机制会导致运行时可以往animals中储存各种类型的对象。
  - 因此,Java此时禁止了List中所有具有泛型输入参数的方法,如:add(T item)

Variance in generics

- **Contravariant in generics:**
  - `List<Animal>` is a subtype of `List<? super Cat>`

```
List<? super Cat> animals = new ArrayList<Animal>();
animals.add(new Cat());
animals.add(new WhiteCat ());
animals.add(new Animal()); //compile error
animals.add(new Object()); //compile error

Animal animal = animals.get(0);  //compile error
Object o = animals.get(1); //succeed, but it is meaningless.
```

  - 对于List中的 T get(int pos)方法，当指定类型是“? super Cat”时，get方法的返回类型就变成了“? super Cat”，即返回类型可能是Cat或者Cat的基类型，compiler无法确定具体类型，因此拒绝调用任何返回类型为T的方法(除非是读取为Object类)
  - 但调用类似add(E e)的方法则安全，传入Cat及其子类(WhiteCat)是安全的，因为compiler知道这个List包含的是Cat或Cat的基类对象。
  - 因此,Java此时禁止了List中所有具有泛型返回类型的方法,如:get()

PECS

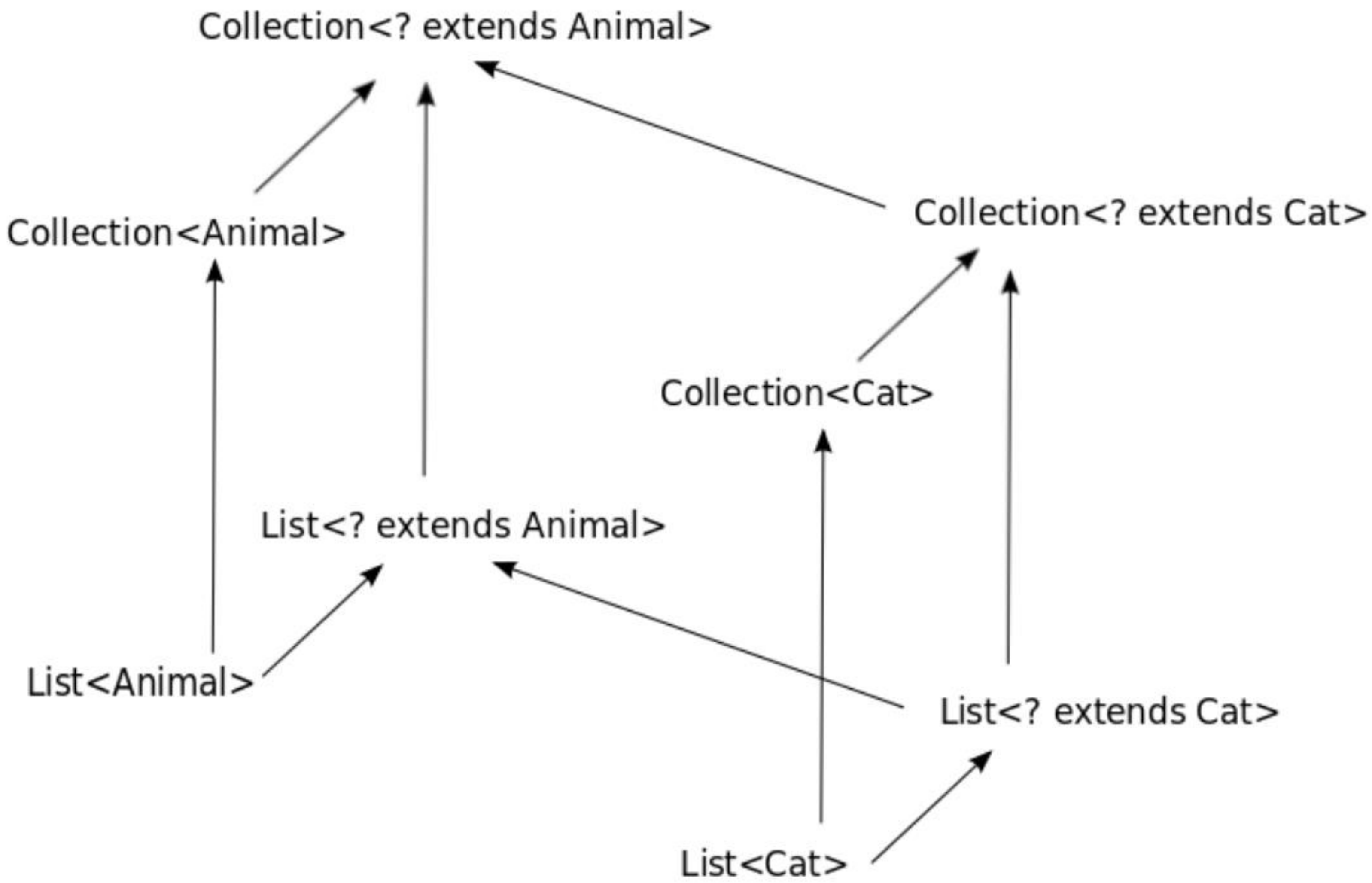
- **Here is a mnemonic(记忆术), PECS (also named Get and Put Principle), to help remember which wildcard type to use:**

  producer-extends, consumer-super

- **The lesson is clear. For maximum flexibility, use wildcard types on input parameters that represent producers or consumers.**
  - If a parameterized type represents a **T producer, use<? extends T>**, e.g., get()
  - If a parameterized type represents a **T consumer, use<? super T>,** e.g., add()

Variance in generics

- **Wildcard subtyping in Java can be visualized as a cube**



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(3) Delegation and Composition

A Sorting example

- **Version A:**

```
static void sort(int[] list, boolean ascending) {
   …
   boolean mustSwap;
   if (ascending) {
      mustSwap = list[i] < list[j];
   } else {
      mustSwap = list[i] > list[j];
   }
   …
}
```

- **Version B:**

Lambda Expressions

```
interface Comparator {
  boolean compare(int i, int j);
}
final Comparator ASCENDING =  (i, j) -> i < j;
final Comparator DESCENDING = (i, j) -> i > j;

static void sort(int[] list, Comparator cmp) {
  …
  boolean mustSwap =
    cmp.compare(list[i], list[j]);
  …
}
```

Delegation 委托

- ***Delegation*** **is simply when one object relies on another object for some subset of its functionality** (one entity passing something to another entity) 委托是指一个对象依赖于另外一个对象的部分功能
  - e.g. here, the `Sorter` is delegating functionality to some `Comparator`
- **Judicious delegation enables code reuse** 委托有利于复用
  - `Sorter` can be reused with arbitrary sort orders
  - `Comparators` can be reused with arbitrary client code that needs to compare integers
- **Explicit delegation:** passing the sending object to the receiving object
- **Implicit delegation:** by the member lookup rules of the language

- **Delegation** can be described as a low level mechanism for sharing code and data between entities. 委托可看做是在实体之间共享代码和数据的低层机制

A simple Delegation example

```java
class RealPrinter {    // the "receiver"
    void print() {
        System.out.println("Hello world!");
    }
}

class Printer {    // the "sender"
    RealPrinter p = new RealPrinter();  // create the receiver
    void print() {
        p.print(); // calls the receiver
    }
}

public class Main {
    public static void main(String[] arguments) {
                // to the outside world it looks like Printer actually prints.
        Printer printer = new Printer();
        printer.print();
    }
}
```

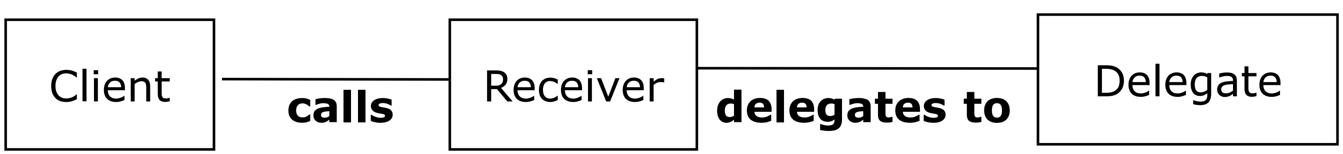
A simple Delegation example

```java
interface I {
    void f();
    void g();
}

class A implements I {
    public void f() { System.out.println("A: doing f()"); }
    public void g() { System.out.println("A: doing g()"); }
}

class B implements I {
    public void f() { System.out.println("B: doing f()"); }
    public void g() { System.out.println("B: doing g()"); }
}

// changing the implementing object in run-time (normally done in compile time)
class C implements I {
    I i = null;
    // forwarding
    public C(I i){ setI(i); }
    public void f() { i.f(); }
    public void g() { i.g(); }

    // normal attributes
    public void setI(I i) { this.i = i; }
}

public class Main {
    public static void main(String[] arguments) {
        C c = new C(new A());
        c.f();   // output: A: doing f()
        c.g();   // output: A: doing g()
        c.setI(new B());
        c.f();   // output: B: doing f()
        c.g();   // output: B: doing g()
    }
}
```

Switch to another forwarder

Delegation

- **The delegation pattern is a software design pattern for implementing delegation, though this term is also used loosely for consultation or forwarding.(也称为转发)**
- **Delegation is dependent upon dynamic binding, as it requires that a given method call can invoke different segments of code at runtime.**
- **Process**
  - The Receiver object delegates operations to the Delegate object
  - The Receiver object makes sure, that the Client does not misuse the Delegate object.



Using delegation to extend functionality

- **Consider `java.util.List`**

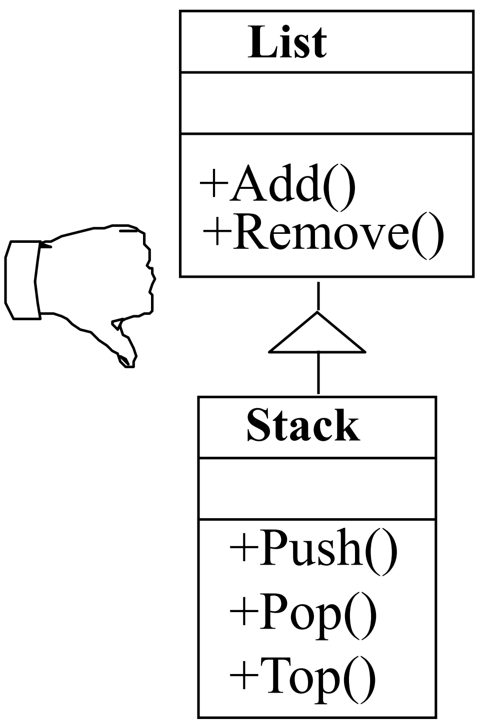
```
public interface List<E> {
  public boolean add(E e);
  public E       remove(int index);
  public void    clear();
  …
}
```

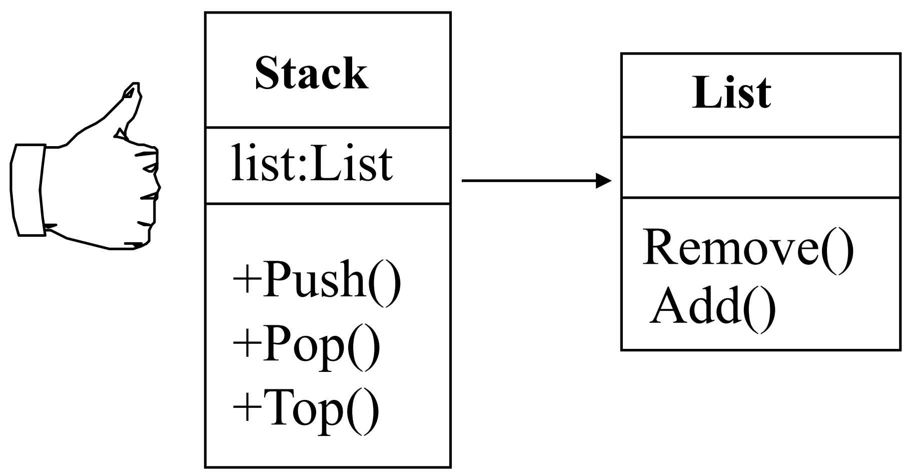
- **Suppose we want a list that logs its operations to the console…**
  – The `LoggingList` *is composed of* a `List`, and delegates (the non-logging) functionality to that `List`.

```
public class LoggingList<E> implements List<E> {
  private final List<E> list;
  public LoggingList<E>(List<E> list) { this.list = list; }
  public boolean add(E e) {
      System.out.println("Adding " + e);
      return list.add(e);
  }
  public E remove(int index) {
      System.out.println("Removing at " + index);
      return list.remove(index);
  }
```

Delegation vs. Inheritance

- **Inheritance: Extending a Base class by a new operation or overwriting an operation.**
- **Delegation: Catching an operation and sending it to another object.**
- **Many design patterns use a combination of inheritance and delegation.**





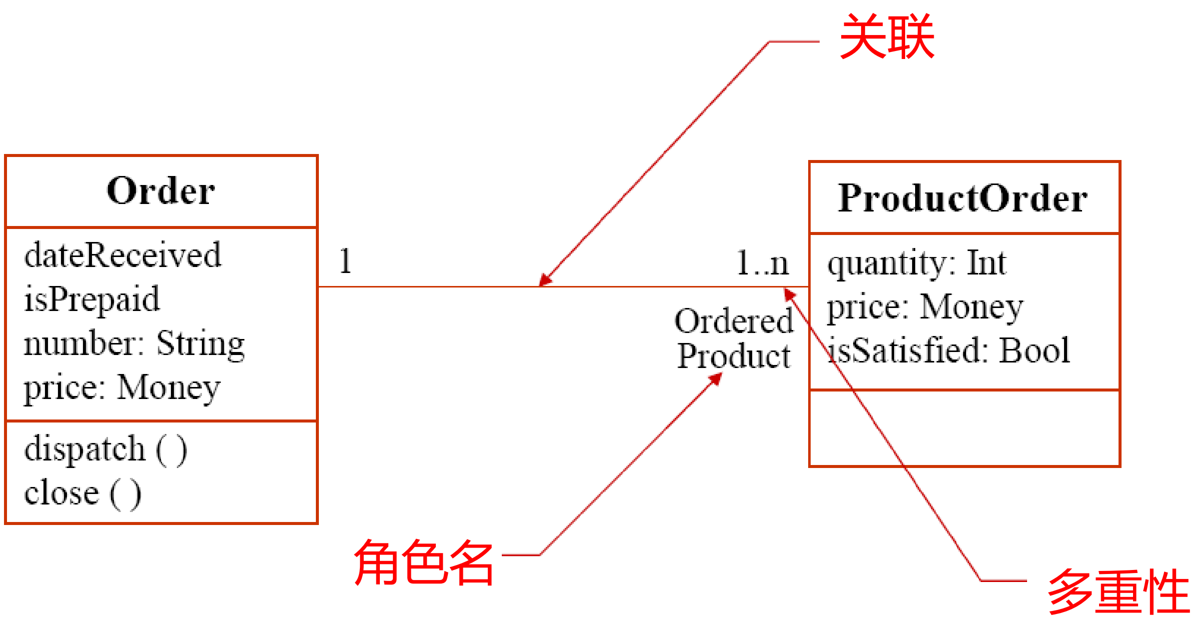
Delegation vs. Inheritance

```
public class A {
    void foo() { this.bar(); }

    void bar() { System.out.println("A.bar"); }
}

public class B extends A {
    public B() {}

    void foo() { super.foo();  }

    void bar() { System.out.println("B.bar"); }
}


    B b = new B();
    b.foo();
```

- **Calling `b.foo()` will result in what?**

Delegation: association关联关系

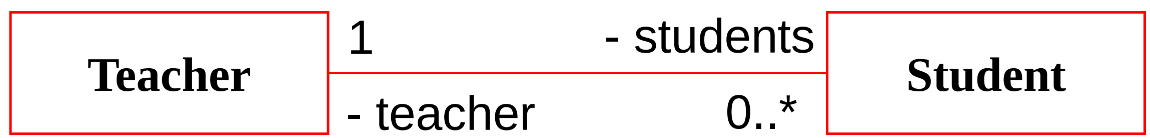
- **Association: a persistent relationship between classes of objects that allows one object instance to cause another to perform an action on its behalf.**
  - This relationship is structural, because it specifies that objects of one kind are connected to objects of another and does not represent behavior.



Delegation: association

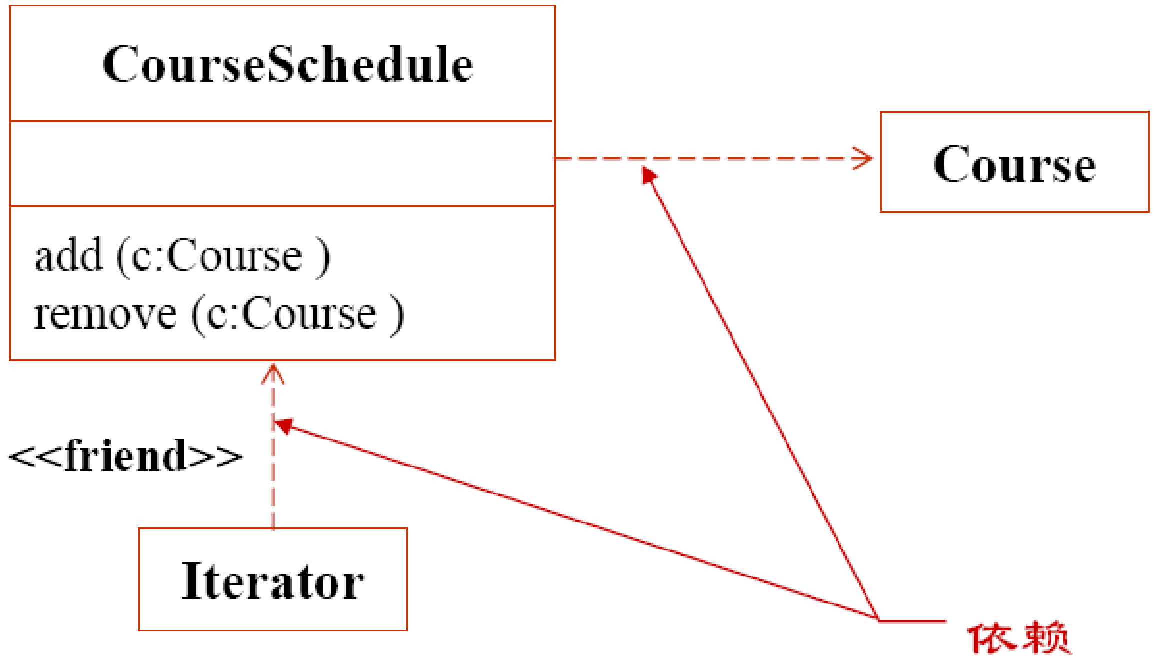
```
class Course {}
class Student {
    private Course [ ] selectedCourses;
}
```

```
class Teacher {
    private Student [ ] students;
}
class Student {
    private Teacher teacher;
}
```



Delegation: dependency 依赖关系

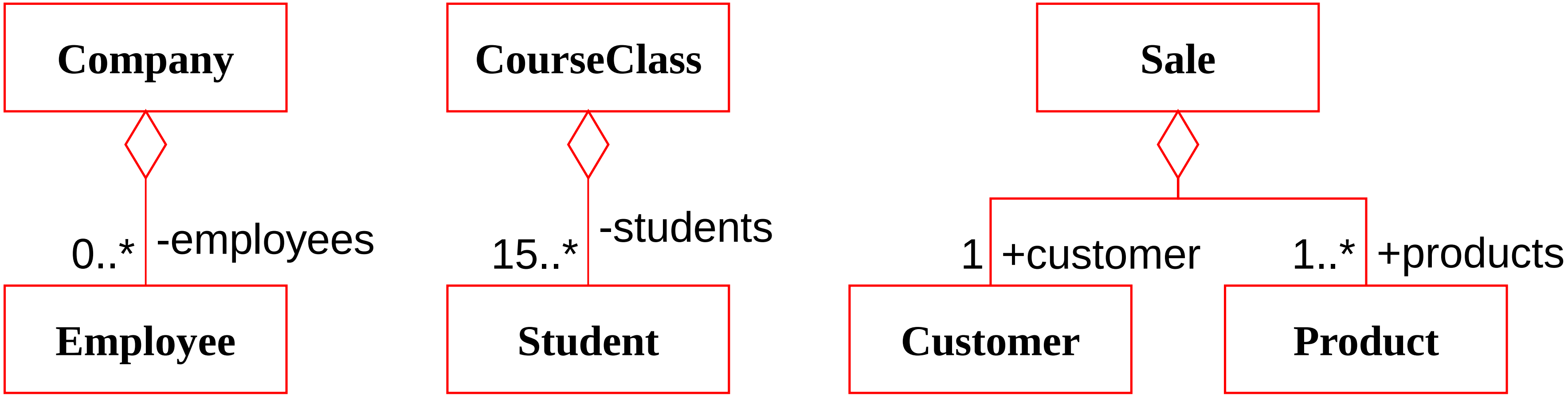
- **Dependency: a temporary relationship that an object requires other objects (suppliers) for their implementation.**



Delegation: composition and aggregation 组合和聚合

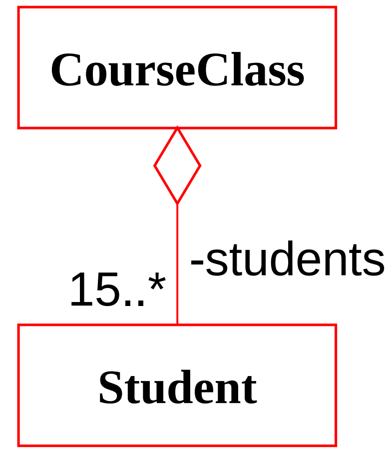
- **Composition is a way to combine simple objects or data types into more complex ones.**
  - An object of a composite type (e.g. `car`) "has an" object of a simpler type (e.g. `wheel`).
  - Composition is implemented such that an object contains another object.
  - **A special composition: aggregation**
- **In composition, when the owning object is destroyed, so are the contained objects. In aggregation, this is not necessarily true.**
  - A university owns various departments, and each department has a number of professors. If the university closes, the departments will no longer exist, but the professors in those departments will continue to exist.
  - A `University` can be seen as a composition of `departments`, whereas `departments` have an aggregation of `professors`. A `Professor` could work in more than one `department`, but a `department` could not be part of more than one `university`. 大学与院系间是组合，院系与教师间是聚合

Delegation: composition and **aggregation**



A company owns zero or multiple employees;
A course's class owns above 15 students;
An Sale owns a customer and a set of products;

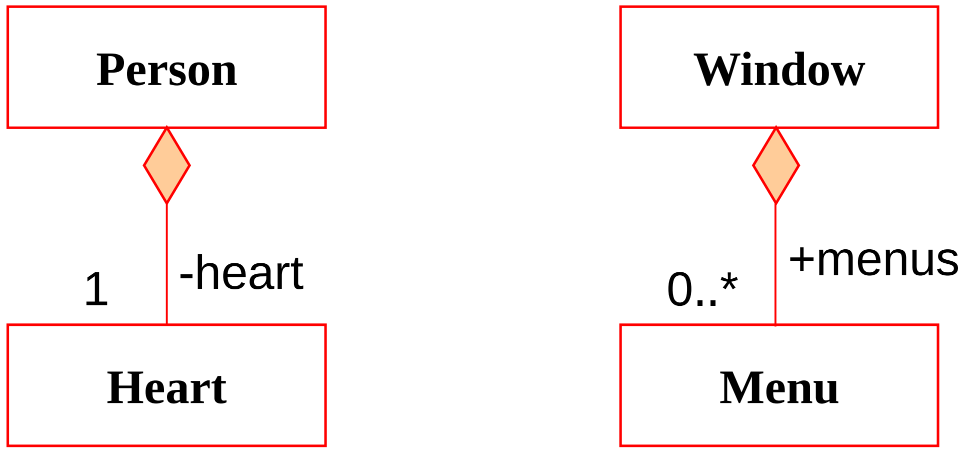
Delegation: composition and **aggregation**




```
class Student {}

class CourseClass {
    ...
    private Student[] students;
    public addStudent (Student s) {
            studtents.append(s);
    }
    ...
}
```

```
Student a = new Student ();
Student b = new Student ();
Student n = new Student ();

CourseClass SE = new CourseClass();
SE.addStudent (a);
SE.addStudent (b);
SE.addStudent (n);
```

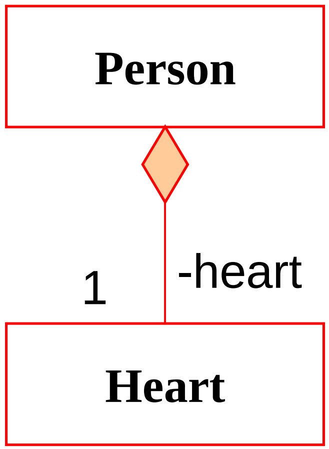
Delegation: **composition** and aggregation



A heart is part of a person;
A menu is part of a window;

Delegation: **composition** and aggregation

```
class Heart {}

class Person {
    ...
    private Heart heart = new Heart();
    ...
}
```



Five types of relations between objects

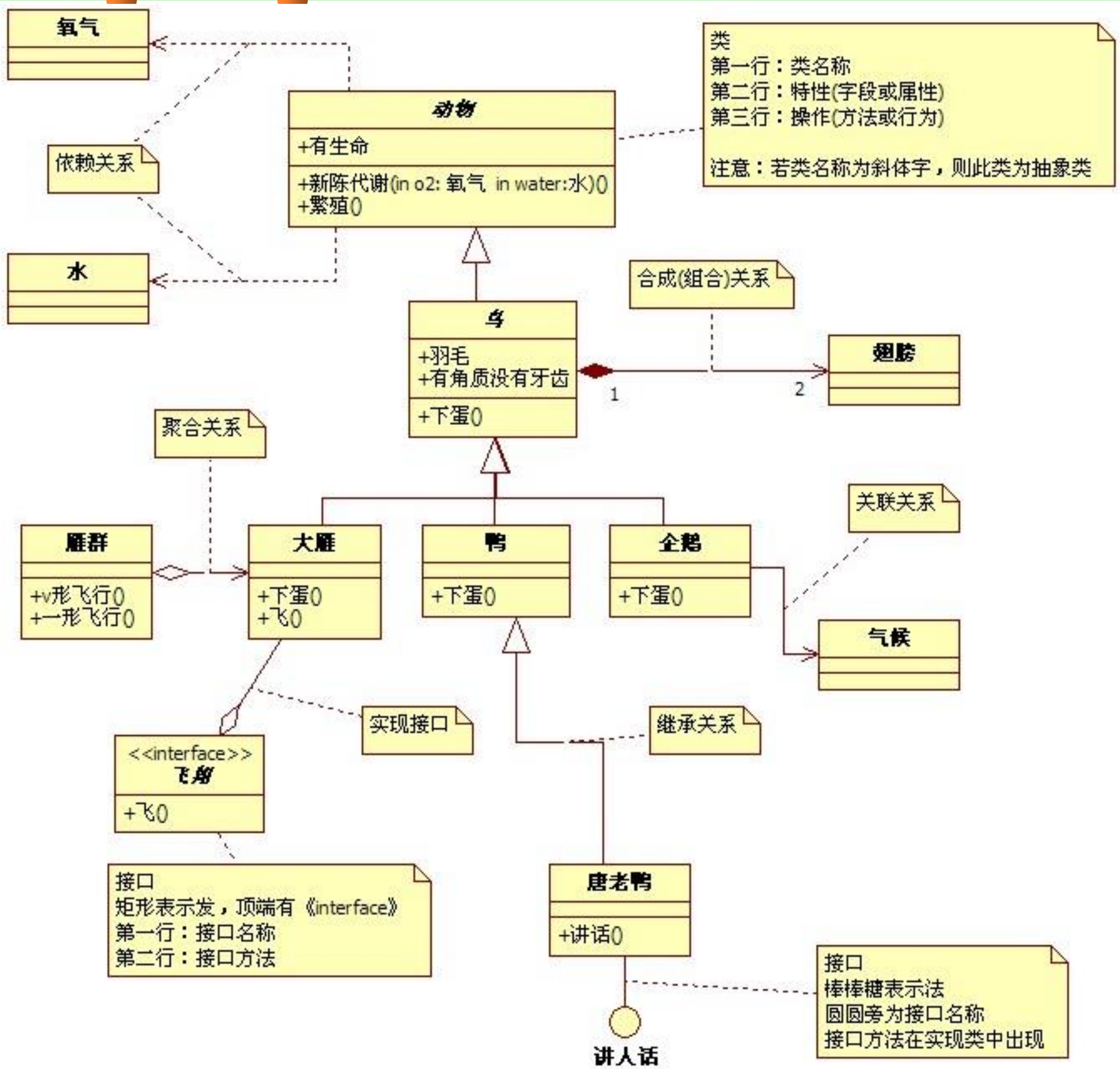
- **Delegation**
  - Association
  - Dependency
  - Composition
  - Aggregation
- **Inheritance**

小结：对象之间的联系

- 继承/泛化inheritance：一般与特殊的关系——is a kind of
- 组合composition：部分与整体的关系，彼此不可分——is part of
- 聚合aggregation：部分与整体的关系，但彼此可分——owns a
- 关联association：对象之间的长期静态联系——has a
- 依赖dependence：对象之间的动态的、临时的通信联系——use a

- 类间联系的强度：继承>>> 组合>> 聚合>> 关联>>> 依赖

面向对象概念的一个综合例子



摘自：http://www.nowamagic.net/architecture/architecture_PicsToIntroduceOOP.php

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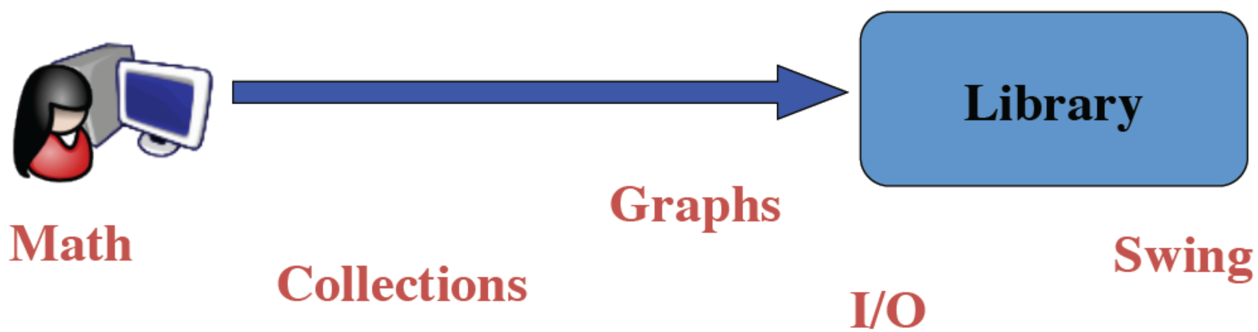
2 Designing system-level reusable libraries and frameworks

Libraries

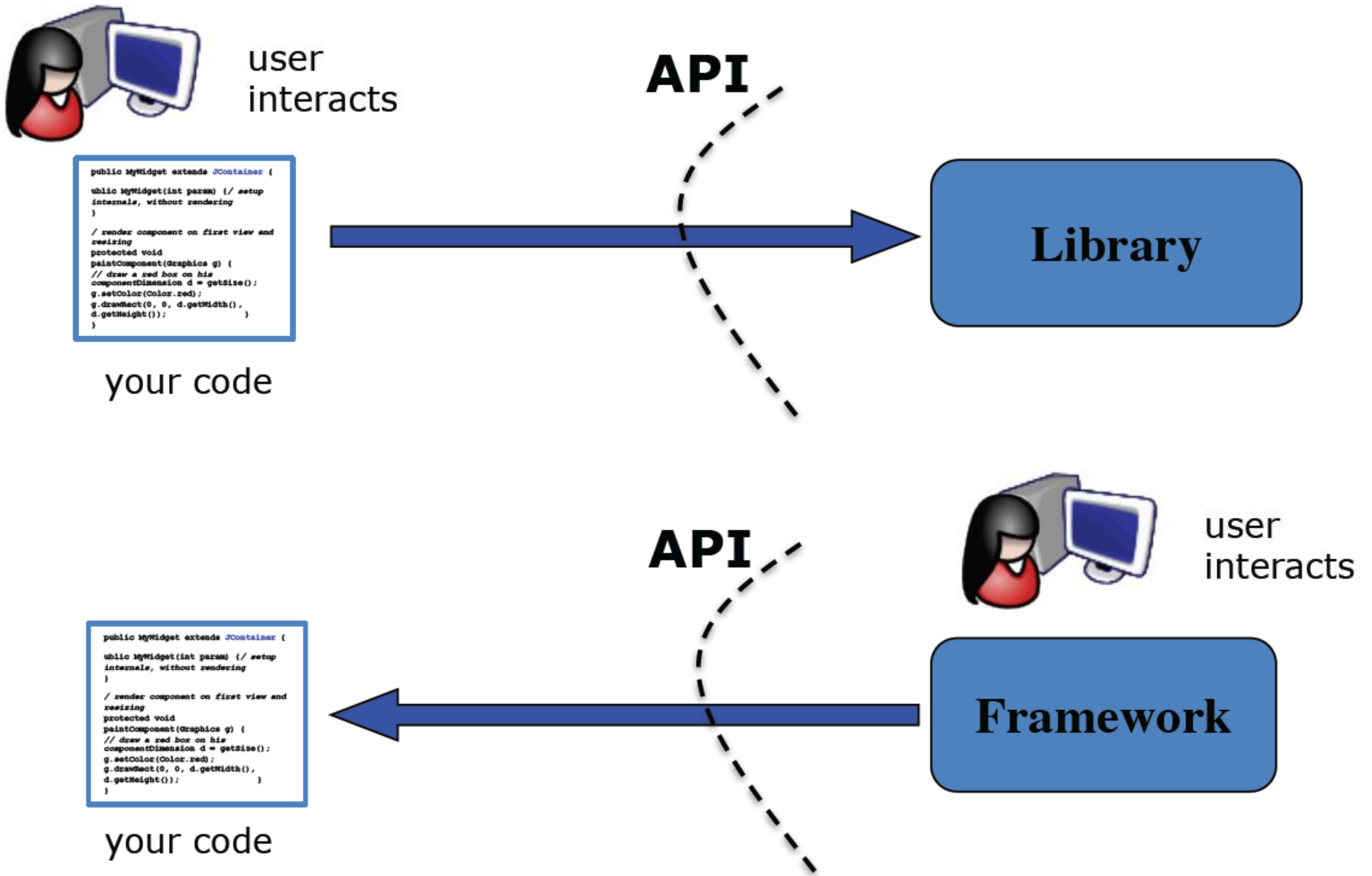
- **Library: A set of classes and methods (APIs) that provide reusable functionality**



Framework

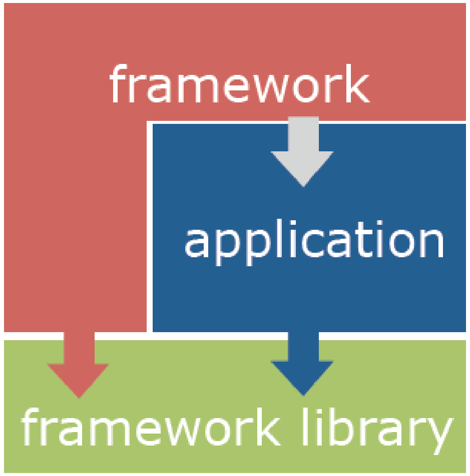
- **Framework: Reusable skeleton code that can be customized into an application**
- **Framework calls back into client code**
  – The Hollywood principle: “Don’t call us. We’ll call you.”

General distinction: Library vs. framework



Libraries and frameworks in practice

- **Defines key abstractions and their interfaces** 定义关键抽象和接口
- **Defines object interactions & invariants** 定义对象不变量和方法
- **Defines flow of control** 定义控制流
- **Provides architectural guidance** 提供构建的指导
- **Provides defaults** 提供缺省实现



More terms

- **API**: Application Programming Interface, the interface of a library or framework
- **Client**: The code that uses an API
- **Plugin**: Client code that customizes a framework
- **Extension point**: A place where a framework supports extension with a plugin
- **Protocol**: The expected sequence of interactions between the API and the client
- **Callback**: A plugin method that the framework will call to access customized functionality
- **Lifecycle method**: A callback method that gets called in a sequence according to the protocol and the state of the plugin

(1) API design

Why is API design important?

- **If you program, you are an API designer, and APIs can be among your greatest assets**
- **Good code is modular – each module has an API**
  - Users invest heavily: acquiring, writing, learning
  - Thinking in terms of APIs improves code quality
  - Successful public APIs capture users
- **Can also be among your greatest liabilities**
  - Bad API can cause unending stream of support calls
  - Can inhibit ability to move forward
- **Public APIs are forever – one chance to get it right** 一旦发布，难以修改
  - Once module has users, can't change API at will

Characteristics of a good API

- **Easy to learn**
- **Easy to use, even without documentation**
- **Hard to misuse**
- **Easy to read and maintain code that uses it**
- **Sufficiently powerful to satisfy requirements**
- **Easy to evolve**
- **Appropriate to audience**

Sample early API draft

```
// A collection of elements (root of the collection hierarchy)
public interface Collection<E> {

  // Ensures that collection contains o
  boolean add(E o);

  // Removes an instance of o from collection, if present
  boolean remove(Object o);

  // Returns true iff collection contains o
  boolean contains(Object o) ;

  // Returns number of elements in collection
  int size() ;

  // Returns true if collection is empty
  boolean isEmpty();

  ... // Remainder omitted

}
```

(1) API should do one thing and do it well

- **Functionality should be easy to explain 功能单一**
  - If it's hard to name, that's generally a bad sign
  - Good names drive development 好的命名利于开发
  - Be amenable to splitting and merging modules 适合分解和合并模块
- **Good:** `Font, Set, PrivateKey, Lock, ThreadFactory, TimeUnit, Future<T>`
- **Bad:**
  - `DynAnyFactoryOperations`
  - `_BindingIteratorImplBase`
  - `ENCODING_CDR_ENCAPS`
  - `OMGVMCID`

(2) API should be as small as possible but no smaller

- **API should satisfy its requirements**
- **When in doubt leave it out**
  - Functionality, classes, methods, parameters, etc.
  - You can always add, but you can never remove 可以增加功能，但不能移除
- **Conceptual weight more important than bulk 追求概念上的"小",而不是体积上的"小"**
- **Look for a good power-to-weight ratio 在性能和大小之间找平衡**

(3) Implementation should not impact API

- **Implementation details in APIs are harmful**
  - Confuse users
  - Inhibit freedom to change implementation
- **Be aware of what is an implementation detail**
  - Do not overspecify the behavior of methods
  - For example: do not specify hash functions
  - All tuning parameters are suspect
- **Don't let implementation details "leak" into API**
  - Serialized forms, exceptions thrown
- **Minimize accessibility of everything (information hiding)**
  - Make classes, members as private as possible
  - Public classes should have no public fields

(4) Documentation matters

- **Document every class, interface, method, constructor, parameter, and exception**
  - Class: what an instance represents
  - Method: contract between method and its client
- **Preconditions, postconditions, side-effects**
  - Parameter: indicate units, form, ownership
- **Document thread safety**
- **If class is mutable, document state space**

Recall Chapter 4 for Understandability

> Reuse is something that is far easier to say than to do. Doing it requires both good design and very good documentation. Even when we see good design, which is still infrequently, we won't see the components reused without good documentation.
>
> – D. L. Parnas
>
> Software Aging, on ICSE 1994

(5) Consider performance consequences

- **Bad decisions can limit performance**
  - Making type mutable
  - Providing constructor instead of static factory
  - Using implementation type instead of interface
- **Do not warp(扭曲) API to gain performance**
  - Underlying performance issue will get fixed, but headaches will be with you forever
- **Good design usually coincides with good performance**
- **Performance effects of a bad API decisions can be real and permanent**
  - `Component.getSize()` returns `Dimension`, but `Dimension` is mutable, thus each `getSize` call must allocate `Dimension`, causing millions of needless object allocations (Dimension类封装了一个构件的高度和宽度)

(6) API must coexist peacefully with platform

- **Do what is customary**
  - Obey standard naming conventions
  - Avoid obsolete parameter and return types
  - Mimic patterns in core APIs and language
- **Take advantage of API-friendly features**
  - Generics, varargs, enums, functional interfaces
- **Know and avoid API traps and pitfalls**
  - Finalizers, public static final arrays, etc.
- **Don’t transliterate(音译) APIs**

(7) Class design

- **Minimize mutability**: Classes should be immutable unless there's a good reason to do otherwise
  - **Advantages:** simple, thread-safe, reusable
  - **Disadvantage:** separate object for each value
  - If mutable, **keep state-space small**, well-defined.
- **Subclass only where it makes sense:** Subclassing implies substitutability (LSP)
  - Don't subclass unless an is-a relationship exists. Otherwise, use delegation or composition. 尽量使用委托和组合
  - Don't subclass just to reuse implementation. 不要因为单纯的复用实现而使用继承
  - Inheritance violates encapsulation, and subclasses are sensitive to implementation details of superclass 继承违反了封装原则

(8) Method design

- **Don't make the client do anything the module could do 模块能做到的，客户端就不要做减少模板代码的使用**
  - Clients generally do via cut-and-paste, which is ugly, annoying, and error-prone.

```
import org.w3c.dom.*;
import java.io.*;
import javax.xml.transform.*;
import javax.xml.transform.dom.*;
import javax.xml.transform.stream.*;

/** DOM code to write an XML document to a specified output stream. */
static final void writeDoc(Document doc, OutputStream out)throws IOException{
  try {
    Transformer t = TransformerFactory.newInstance().newTransformer();
    t.setOutputProperty(OutputKeys.DOCTYPE_SYSTEM, doc.getDoctype().getSystemId());
    t.transform(new DOMSource(doc), new StreamResult(out)); // Does actual writing
  } catch(TransformerException e) {
    throw new AssertionError(e);  // Can't happen!
  }
}
```

- **APIs should fail fast: report errors as soon as possible. Compile time is best – static typing, generics.**
  - At runtime, first bad method invocation is best
  - Method should be failure-atomic**(要么正常结束，产生期望结果；要么整体失败，不产生任何的结果)**

(8) Method design

- **Provide programmatic access to all data available in string form.** Otherwise, clients will parse strings, which is painful for clients **对所有可访问数据提供String形式的访问方法，避免客户端去解析**

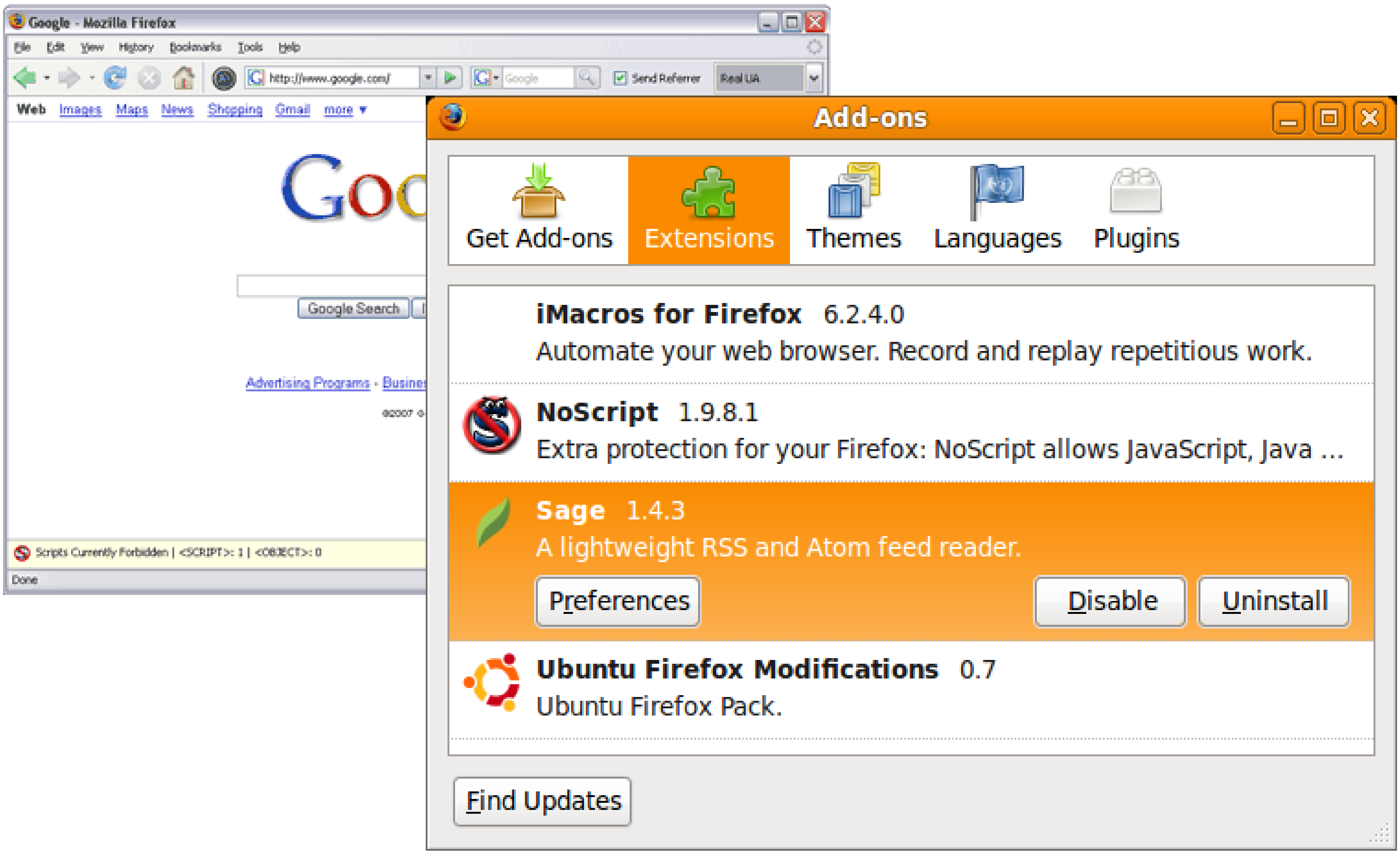
```
public class Throwable {
    public void printStackTrace(PrintStream s);
    public StackTraceElement[] getStackTrace(); // Since 1.4 }
    public final class StackTraceElement {
        public String getFileName();
        public int getLineNumber();
        public String getClassName();
        public String getMethodName();
        public boolean isNativeMethod();
    }
}
```

(8) Method design

- **Overload with care.** Often better to use a different name.
- **Use appropriate parameter & return types.**
  - Favor interface types over classes for input for flexibility, performance
  - Use most specific possible input parameter type, thus moves error from runtime to compile time.
- **Avoid long parameter lists.** Three or fewer parameters is ideal.
  - What if you have to use many parameters?
- **Avoid return values that demand exceptional processing**. Return zero-length array or empty collection, not null.返回值勿需进行异常处理, **e.g., 用空集合或者0长度数组, 不要用null**

(2) Framework design

An example: web browser plugin



Whitebox and Blackbox frameworks

- **Whitebox frameworks**
  - Extension via subclassing and overriding methods
  - Common design pattern(s): Template Method
  - Subclass has main method but gives control to framework

- **Blackbox frameworks**
  - Extension via implementing a plugin interface
  - Common design pattern(s): Strategy, Observer
  - Plugin-loading mechanism loads plugins and gives control to the framework

A calculator example (without a framework)


```
public class Calc extends JFrame {
  private JTextField textField;
  public Calc() {
      JPanel contentPane = new JPanel(new BorderLayout());
      contentPane.setBorder(new BevelBorder(BevelBorder.LOWERED));
      JButton button = new JButton();
      button.setText("calculate");
      contentPane.add(button, BorderLayout.EAST);
      textField = new JTextField("");
      textField.setText("10 / 2 + 6");
      textField.setPreferredSize(new Dimension(200, 20));
      contentPane.add(textfield, BorderLayout.WEST);
      button.addActionListener(/* calculation code */);
      this.setContentPane(contentPane);
      this.pack();
      this.setLocation(100, 100);
      this.setTitle("My Great Calculator");
      ...
  }
}
```

A simple whitebox framework

```
public abstract class Application extends JFrame {
  protected String getApplicationTitle() { return ""; }
  protected String getButtonText() { return ""; }
  protected String getInitialText() { return ""; }
  protected void buttonClicked() { }
  private JTextField textField;
  public Application() {
      JPanel contentPane = new JPanel(new BorderLayout());
      contentPane.setBorder(new BevelBorder(BevelBorder.LOWERED));
      JButton button = new JButton();
      button.setText(getButtonText());
      contentPane.add(button, BorderLayout.EAST);
      textField = new JTextField("");
      textField.setText(getInitialText());
      textField.setPreferredSize(new Dimension(200, 20));
      contentPane.add(textField, BorderLayout.WEST);
      button.addActionListener((e) -> { buttonClicked(); });
      this.setContentPane(contentPane);
      this.pack();
      this.setLocation(100, 100);
      this.setTitle(getApplicationTitle());
      ...
  }
```

Using the whitebox framework

```java
public class Calculator extends Application {
  protected String getApplicationTitle() { return "My Great Calculator"; }
  protected String getButtonText() { return "calculate"; }
  protected String getInititalText() { return "(10 - 3) * 6"; }
  protected void buttonClicked() {
    JOptionPane.showMessageDialog(this, "The result of " + getInput() +
        " is " + calculate(getInput()));
  }
  private String calculate(String text) { ... }
}
```

Extension via subclassing and overriding methods
Subclass has main method but gives control to framework

```java
public class Ping extends Application {
  protected String getApplicationTitle() { return "Ping"; }
  protected String getButtonText() { return "ping"; }
  protected String getInititalText() { return "127.0.0.1"; }
  protected void buttonClicked() { ... }
}
```

An example blackbox framework

```
public interface Plugin {
  String getApplicationTitle();
  String getButtonText();
  String getInititalText();
  void buttonClicked() ;
  void setApplication(Application app);
}
```

```
public class Application extends JFrame {
   private JTextField textField;
   private Plugin plugin;
   public Application() { }
   protected void init(Plugin p) {
     p.setApplication(this);
     this.plugin = p;
     JPanel contentPane = new JPanel(new BorderLayout());
     contentPane.setBorder(new BevelBorder(BevelBorder.LOWERED));
     JButton button = new JButton();
     button.setText(plugin != null ? plugin.getButtonText() : "ok");
     contentPane.add(button, BorderLayout.EAST);
     textField = new JTextField("");
     if (plugin != null)
         textField.setText(plugin.getInititalText());
     textField.setPreferredSize(new Dimension(200, 20));
     contentPane.add(textField, BorderLayout.WEST);
     if (plugin != null)
         button.addActionListener((e) -> { plugin.buttonClicked(); } );
     this.setContentPane(contentPane);
    ...
  }
  public String getInput() { return textField.getText(); }
}
```

Using the blackbox framework

```
public class CalcPlugin implements Plugin {
  private Application app;
  public void setApplication(Application app) { this.app = app; }
  public String getButtonText() { return "calculate"; }
  public String getInititalText() { return "10 / 2 + 6"; }
  public void buttonClicked() {
      JOptionPane.showMessageDialog(null, "The result of "
               + application.getInput() + " is "
               + calculate(application.getInput()));
  }
  public String getApplicationTitle() { return "My Great Calculator"; }
}
```

Extension via implementing a plugin interface
Plugin-loading mechanism loads plugins and gives control to the framework

Whitebox vs. Blackbox Frameworks

- **Whitebox frameworks use subclassing**
  - Allows extension of every nonprivate method
  - Need to understand implementation of superclass
  - Only one extension at a time
  - Compiled together
  - **Often so-called developer frameworks**
- **Blackbox frameworks use composition**
  - Allows extension of functionality exposed in interface
  - Only need to understand the interface
  - Multiple plugins
  - Often provides more modularity
  - Separate deployment possible (.jar, .dll, …)
  - **Often so-called end-user frameworks, platforms**

Framework design considerations

- **Once designed there is little opportunity for change**
- **Key decision: Separating common parts from variable parts**
  - What problems do you want to solve?
- **Possible problems:**
  - Too few extension points: Limited to a narrow class of users
  - Too many extension points: Hard to learn, slow
  - Too generic: Little reuse value

"Maximizing reuse minimizes use"

Typical framework design and implementation

- **Define your domain**
  - Identify potential common parts and variable parts
  - Design and write sample plugins/applications
- **Factor out & implement common parts as framework**
- **Provide plugin interface & callback mechanisms for variable parts**
  - Use well-known design principles and patterns where appropriate…
- **Get lots of feedback, and iterate**

- **This is usually called “Domain Engineering”.**

Evolutionary design: Extract Commonalities 获取共性

- **Extracting interfaces is a new step in evolutionary design:**
  - **Abstract classes are discovered from concrete classes**
  - **Interfaces are distilled from abstract classes**
- **Start once the architecture is stable**
  - **Remove non-public methods from class**
  - **Move default implementations into an abstract class which implements the interface**

Running a framework

- **Some frameworks are runnable by themselves**
  - e.g. Eclipse
- **Other frameworks must be extended to be run**
  - Swing, JUnit, MapReduce, Servlets
- **Methods to load plugins:**
  - **Client writes main()**, creates a plugin and passes it to framework
  - **Framework writes main(),** client passes name of plugin as a command line argument or environment variable
  - **Framework looks in a magic location**, and then config files or .jar files are automatically loaded and processed.

Example: An Eclipse plugin

- **Eclipse is a** popular Java IDE.
- **More generally, a framework for tools that facilitate "building, deploying and managing software across the lifecycle."**
- **Plugin framework based on OSGI standard**
- **Starting point: Manifest file**
  - Plugin name
  - Activator class
  - Meta-data

```
Manifest-Version: 1.0
Bundle-ManifestVersion: 2
Bundle-Name: MyEditor Plug-in
Bundle-SymbolicName: MyEditor;
singleton:=true
Bundle-Version: 1.0.0
Bundle-Activator:
 myeditor.Activator
Require-Bundle:
 org.eclipse.ui,
 org.eclipse.core.runtime,
 org.eclipse.jface.text,
 org.eclipse.ui.editors
Bundle-ActivationPolicy: lazy
Bundle-
RequiredExecutionEnvironment:
JavaSE-1.6
```

Example: An Eclipse plugin

- **plugin.xml**
  - Main configuration file
  - XML format
  - Lists extension points
- **Editor extension**
  - extension point: org.eclipse.ui.editors
  - file extension
  - icon used in corner of editor
  - class name
  - unique id
    - refer to this editor
    - other plugins can extend with new menu items, etc.!
- At last, code!
- XMLEditor.java
  - Inherits TextEditor behavior such as open, close, save, display, select, cut/copy/paste, search/replace, …
  - Extends with syntax highlighting
  - XMLDocumentProvider partitions into tags and comments
  - XMLConfiguration shows how to color partitions

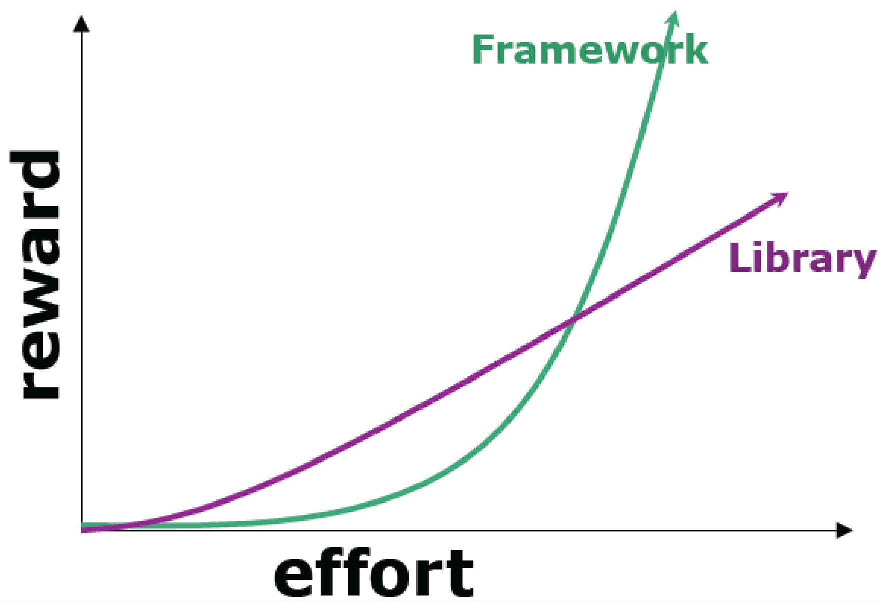
Example: A JUnit Plugin

```
public class SampleTest  {
      private List<String> emptyList;

      @Before
      public void setUp() {
          emptyList = new ArrayList<String
      }

     @After
      public void tearDown() {
          emptyList = null;
      }

     @Test
      public void testEmptyList() {
          assertEquals("Empty list should have 0 elements",
                       0, emptyList.size());
      }
}
```

In JUnit the plugin mechanism is Java annotations

Learning a framework

- Documentation
- Tutorials, wizards, and examples
- Other client applications and plugins
- Communities, email lists and forums



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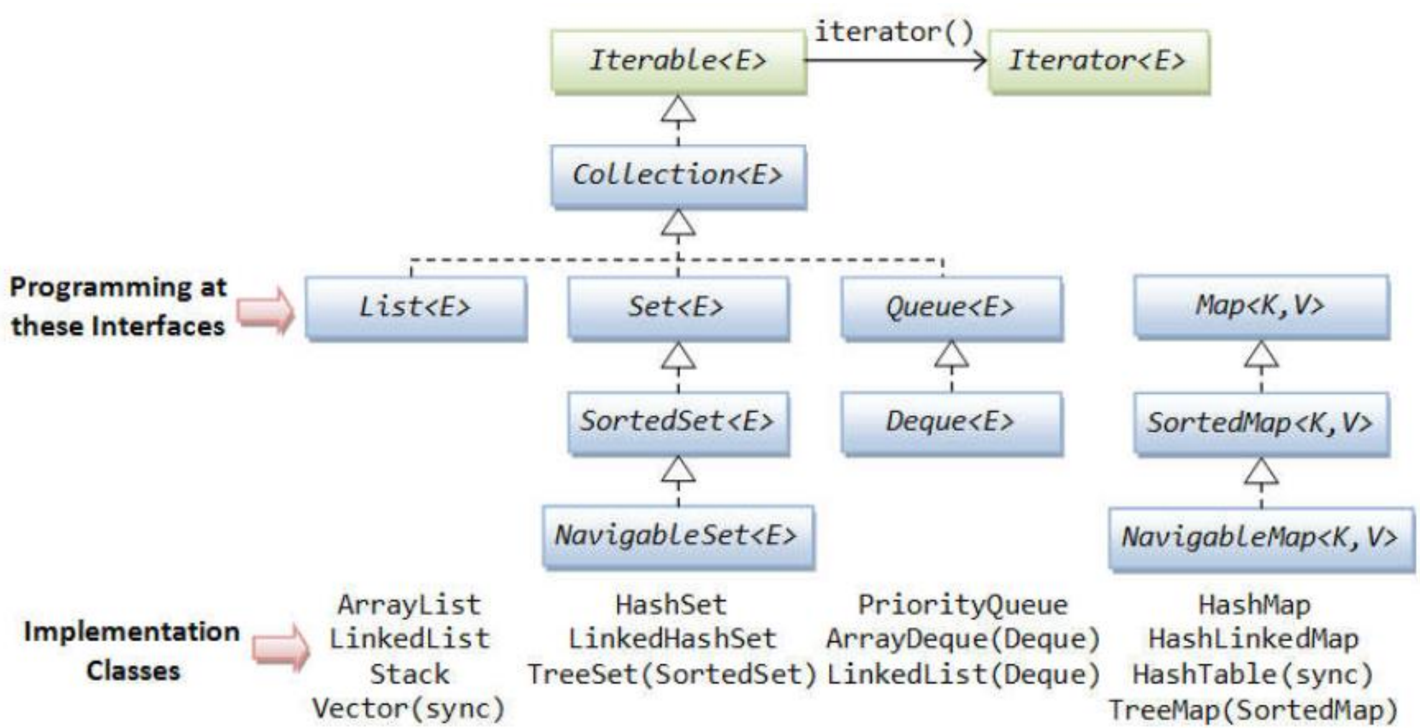
(3) Java Collections Framework

What is a Collection and Collection Framework?

- **Collection: an object that groups elements**
- **Main Uses:** data storage and retrieval, and data transmission
- **Familiar Examples**
  - `java.util.ArrayList`
  - `java.util.Hashtable`
  - `Java.util.Queue`
- **Collection Framework:** a Unified Architecture for
  - Interfaces - implementation-independence
  - Implementations - reusable data structures
  - Algorithms - reusable functionality
- **Best-known examples**
  - C++ Standard Template Library (STL)

Architecture Overview

- Core Collection Interfaces
- General-Purpose Implementations
- Wrapper Implementations
- Abstract Implementations
- Algorithms



Collection Interface

```
public interface Collection<E> {
  int size();
  boolean isEmpty();
  boolean contains(Object o);
  boolean add(E e); // Optional
  boolean remove(Object o); // Optional
  Iterator<E> iterator();
  Object[] toArray();
  <T> T[] toArray(T a[]);

  // Bulk Operations
  boolean containsAll(Collection<?> c);
  boolean addAll(Collection<? Extends E> c); // Optional
  boolean removeAll(Collection<?> c);        // Optional
  boolean retainAll(Collection<?> c);        // Optional
  void clear(); // Optional
}
```

Iterator Interface

- **Replacement for Enumeration interface** 替换了枚举接口
  - Adds remove method
  - Improves method names

```
public interface Iterator<E> {
   boolean hasNext();
   E next();
   void remove(); // Optional
}
```

Set Interface

- Adds no methods to Collection!
- Adds stipulation: no duplicate elements 增加无重复元素的要求
- Mandates equals and hashCode calculation 强制equals和hashCode计算

```
public interface Set<E> extends Collection<E> {
}
```

- Set Idioms:

```
Set<Type> s1, s2;
boolean isSubset = s1.containsAll(s2);
Set<Type> union = new HashSet<>(s1);
union = union.addAll(s2);
Set<Type> intersection = new HashSet<>(s1);
intersection.retainAll(s2);
Set<Type> difference = new HashSet<>(s1);
difference.removeAll(s2);
Collection<Type> c;
Collection<Type> noDups = new HashSet<>(c);
```

List Interface: a sequence of objects

```
public interface List<E> extends Collection<E> {

  E get(int index);
  E set(int index, E element);        // Optional
  void add(int index, E element);     // Optional
  Object remove(int index);           // Optional
  boolean addAll(int index, Collection<? extends E> c);
                                      // Optional

  int indexOf(Object o);
  int lastIndexOf(Object o);

  List<E> subList(int from, int to);

  ListIterator<E> listIterator();
  ListIterator<E> listIterator(int index);
}
```

List Example

- **Reusable algorithms to swap and randomize:**

```java
public static <E> void swap(List<E> a, int i, int j) {
    E tmp = a.get(i);
    a.set(i, a.get(j));
    a.set(j, tmp);
}
private static Random r = new Random();
public static void shuffle(List<?> a) {
    for (int i = a.size(); i > 1; i--)
        swap(a, i - 1, r.nextInt(i));
}
```

- **List Idioms:**

```java
List<Type> a, b;
a.addAll(b); // Concatenate two lists
a.subList(from, to).clear(); // Range-remove
// Range-extract
List<Type> partView = a.subList(from, to);
List<Type> part = new ArrayList<>(partView);
partView.clear();
```

Map Interface: a Key-Value mapping

```
public interface Map<K,V> {

    int size();
    boolean isEmpty();
    boolean containsKey(Object key);
    boolean containsValue(Object value);

    Object get(Object key);
    Object put(K key, V value);                          // Optional
    Object remove(Object key);                           // Optional
    void putAll(Map<? Extends K, ? Extends V> t);        // Optional
    void clear();                                        // Optional

    // Collection Views
    public Set<K> keySet();
    public Collection<V> values();
    public Set<Map.Entry<K,V>> entrySet();
}
```

Map Idioms

```
// Iterate over all keys in Map m
Map<Key, Val> m;
for (iterator<Key> i = m.keySet().iterator(); i.hasNext(); )
   System.out.println(i.next());

// As of Java 5 (2004)
for (Key k : m.keySet())
   System.out.println(i.next());

// “Map algebra“ 代数操作
Map<Key, Val> a, b;
boolean isSubMap = a.entrySet().containsAll(b.entrySet());//子集

a.keySet().retainAll(b.keySet());
Set<Key> commonKeys = new HashSet<>(a.keySet()); //交集

//Remove keys from a that have mappings in b
a.keySet().removeAll(b.keySet());  //差集
```

General Purpose Implementations

- **Consistent Naming and Behavior**

		Implementations			
		Hash Table	Resizable Array	Balanced Tree	Linked List
Interfaces	Set	HashSet		TreeSet	
	List		ArrayList		Linked List
	Map	HashMap		TreeMap	

Choosing an Implementation

- `Set`
  - `HashSet` -- O(1) access, no order guarantee
  - `TreeSet` -- O(log n) access, sorted
- `Map`
  - `HashMap` -- (See `HashSet`)
  - `TreeMap` -- (See `TreeSet`)
- `List`
  - `ArrayList` -- O(1) random access, O(n) insert/remove
  - `LinkedList` -- O(n) random access, O(1) insert/remove;
    - Use for queues and deques (no longer a good idea!)

Unmodifiable Wrappers

- **Anonymous implementations**
- **Static factory methods**
- **One for each core interface**
- **Provide read-only access – Immutable!**

- **We have discussed these wrapper in Chapter 3**

Synchronization Wrappers

- **Not thread-safe!**
- **Synchronization Wrappers: a new approach to thread safety**
  - Anonymous implementations, one per core interface
  - Static factories take collection of appropriate type
  - Thread-safety assured if all access through wrapper
  - Must manually synchronize iteration
- **It was new then; it's old now! 同步包装器的方式现在已经过时**
  - Synch wrappers are largely obsolete
  - Made obsolete by concurrent collections 已经被并行容器所替代
- **To be discussed in Chapter 10**

Synchronization Wrapper Example

```
Set<String> s = Collections.synchronizedSet(new
HashSet<>());
...
s.add("wombat"); // Thread-safe
...
synchronized(s) {
  Iterator<String> i = s.iterator(); // In synch block!
  while (i.hasNext())
      System.out.println(i.next());
}

// In Java 5 (post-2004)
synchronized(s) {
  for (String t : s)
      System.out.println(i.next());
}
```

Convenience Implementations

- `Arrays.asList(E[] a)`
  - Allows array to be "viewed" as `List`
  - Bridge to Collection-based APIs
- `EMPTY_SET, EMPTY_LIST, EMPTY_MAP`
  - Immutable constants **不支持add操作**
- `singleton(E o)` **返回只包含指定对象的不可变集**
  - Immutable set with specified object
- `nCopies(int n, T o)` **返回由指定对象n个副本构成的不可变List。**
  - Immutable list with `n` copies of object

Reusable Algorithms

```
static <T extends Comparable<? super T>> void sort(List<T> list);
static int binarySearch(List list, Object key);
static <T extends Comparable<? super T>> T min(Collection<T> coll);
static <T extends Comparable<? super T>> T max(Collection<T> coll);
static <E> void fill(List<E> list, E e);
static <E> void copy(List<E> dest, List<? Extends E> src);
static void reverse(List<?> list);
static void shuffle(List<?> list);
```

Example 1: Sorting lists of comparable elements

```
List<String> strings; // Elements type: String
...
Collections.sort(strings); // Alphabetical order

LinkedList<Date> dates; // Elements type: Date
...
Collections.sort(dates); // Chronological order

// Comparable interface (Infrastructure)
public interface Comparable<E extends Comparable<E>> {
   int compareTo(Object o);
}
```

Algorithm Example 2: Sorting with a comparator

```
List<String> strings; // Element type: String
Collections.sort(strings, Collections.ReverseOrder()); //采用反序比较器
```

```
//自定义比较器: Case-independent alphabetical order
static Comparator<String> cia = new Comparator<>() {
   public int compare(String c1, String c2) {
      return c1.toLowerCase().compareTo(c2.toLowerCase());
   }
};

Collections.sort(strings, cia);

public interface Comparator<T> {
   public int compare(T o1, T o2);
}
```

Compatibility

- **Old and new collections interoperate freely**

- **Upward Compatibility** **向上兼容/向前兼容(forward)，站在旧版软件的立场，基于旧方法编写的软件不经修改就能在新版环境中运行**
  - ```
    Vector<E> implements List<E>
    ```
  - ```
    Hashtable<K,V> implements Map<K,V>
    ```
  - ```
    Arrays.asList(myArray)
    ```
- **Backward Compatibility** **向后兼容/向下兼容(downward)，站在新版本的立场讨论对过去版本的兼容性问题，新版软件中可以支持旧版中的方法**
  - ```
    myCollection.toArray()
    ```
  - ```
    new Vector<>(myCollection)
    ```
  - ```
    new HashTable<>(myMap)
    ```

API Design Guidelines

- **Avoid ad hoc collections 避免特定的容器类型**
  - Input parameter type:
    - Any collection interface (Collection, Map best)
    - Array may sometimes be preferable
  - Output value type:
    - Any collection interface or class
    - Array
- **Provide adapters for your legacy collections**

Summary

The end

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