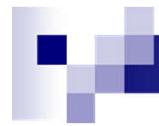
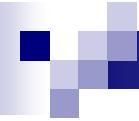


Containment in Unions and Methods



Part 1: Containment in union Self-References and Mutual References

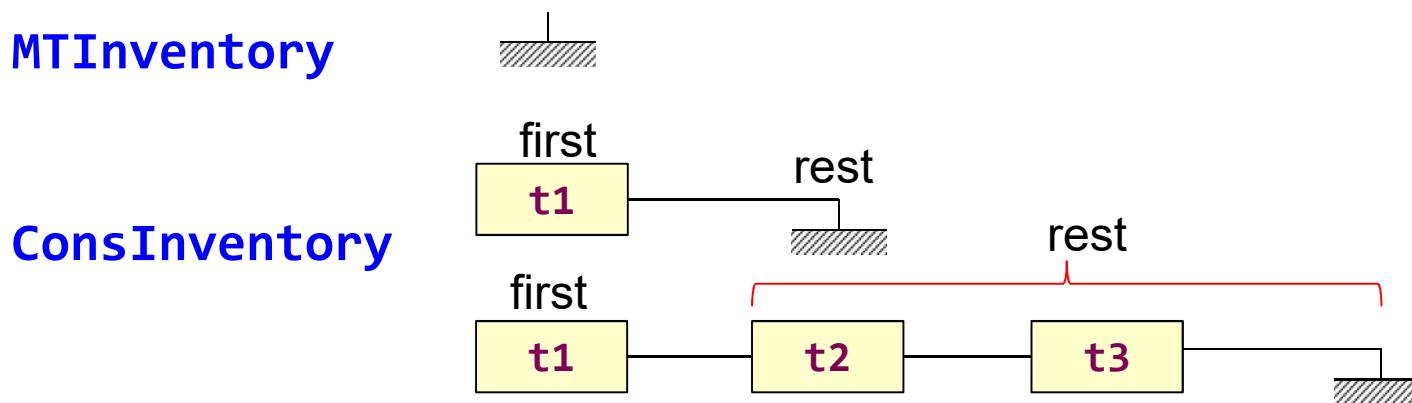


Managing Inventory

- A sales clerk in a toy store needs to know not only the name of the toy, but also its price, warehouse availability.
- The representation of an inventory as a **list of toys**.

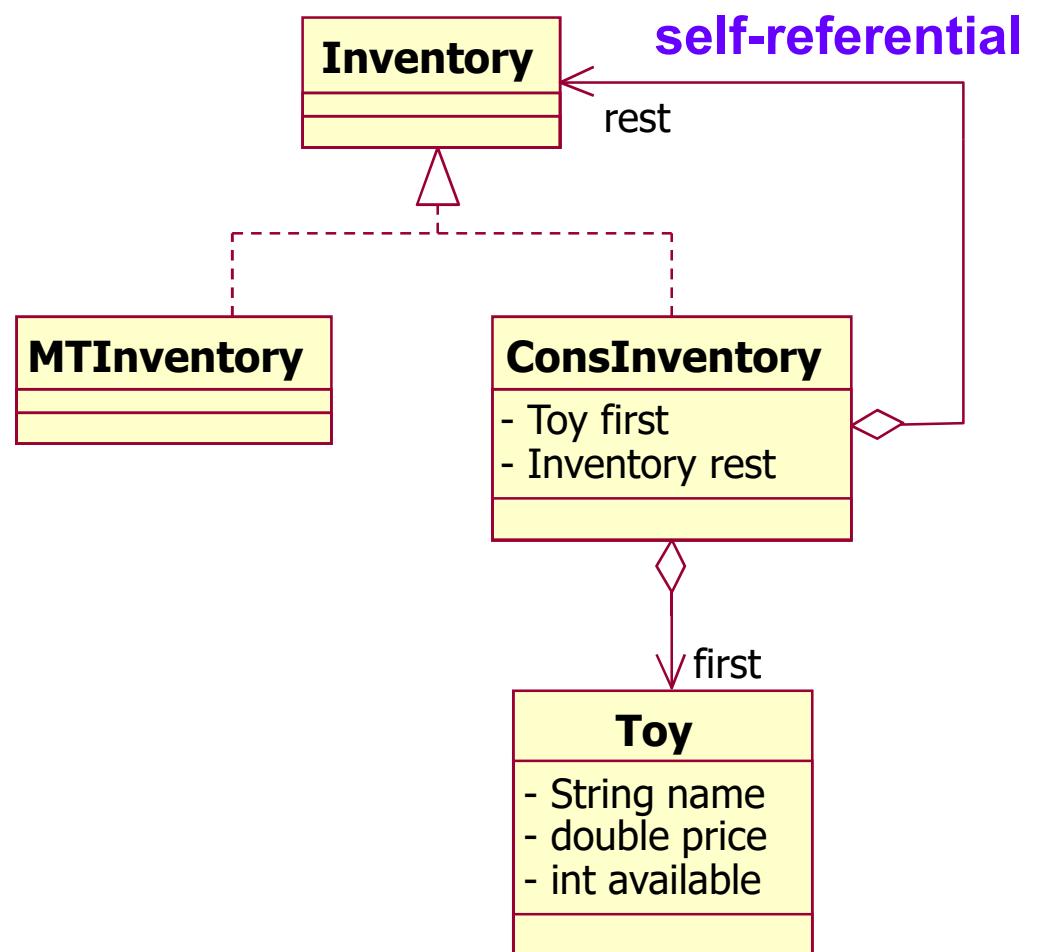
Data definition

- **Inventory** is one of:
 - a **empty**
 - a **construct** of **Toy Inventory**
- The class of **Inventory** is a union:
 - **Inventory**, which is the type of all kind of inventories;
 - **MTInventory**, which represents an empty inventory; and
 - **ConsInventory**, which represents the construction of a new inventory from a **Toy** and an existing **Inventory**.



Class diagram

- An **MTInventory** class don't have any fields for it.
- A **ConsInventory** class requires two field definitions:
 - one for the first **Toy**
 - and one for the **rest of the Inventory**.



Define classes and constructors

```
public interface Inventory {  
}
```

```
public class MTInventory implements Inventory {  
}
```

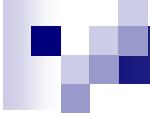
```
public class ConsInventory implements Inventory {  
    private Toy first;  
    private Inventory rest;  
    public ConsInventory(Toy first, Inventory rest) {  
        this.first = first;  
        this.rest = rest;  
    }  
}
```

Define classes and constructors

```
public class Toy {  
    private String name;  
    private double price;  
    private int available;  
  
    public Toy(String name, double price,  
              int available) {  
        this.name = name;  
        this.price = price;  
        this.available = available;  
    }  
}
```

Test Constructor

```
public class InventoryTest extends TestCase {  
    public void testConstructor() {  
        Toy doll = new Toy("doll", 17.95, 5);  
        Toy robot = new Toy("robot", 22.05, 3);  
        Toy gun = new Toy ("gun", 15.0, 4);  
  
        Inventory empty = new MTInventory();  
        Inventory i1 = new ConsInventory(gun, empty);  
        Inventory i2 = new ConsInventory(robot, i1);  
        Inventory i3 = new ConsInventory(doll, i2);  
        System.out.println(i3);  
  
        Inventory all = new ConsInventory(doll,  
                                         new ConsInventory(robot,  
                                         new ConsInventory(gun, new MTInventory()))));  
        System.out.println(all);  
    }  
}
```



Print the content of an inventory

Q: How can we print the content of an object.

A: overriding `toString()` method of class `Object`.

Q: Do we need to add `toString()` in
`Inventory` class?

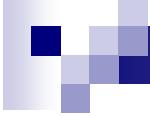
A: No !

toString() in classes

```
// inside of MTInventory class
public String toString() {
    return "";
}

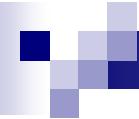
// inside of ConsInventory class
public String toString() {
    return this.first.toString() + "\n"
        + this.rest.toString();
}
```

```
// inside of Toy class
public String toString() {
    return "name: " + this.name
        + ", price: " + this.price
        + ", available: " + this.available;
}
```



Managing a Runner's Logs Example

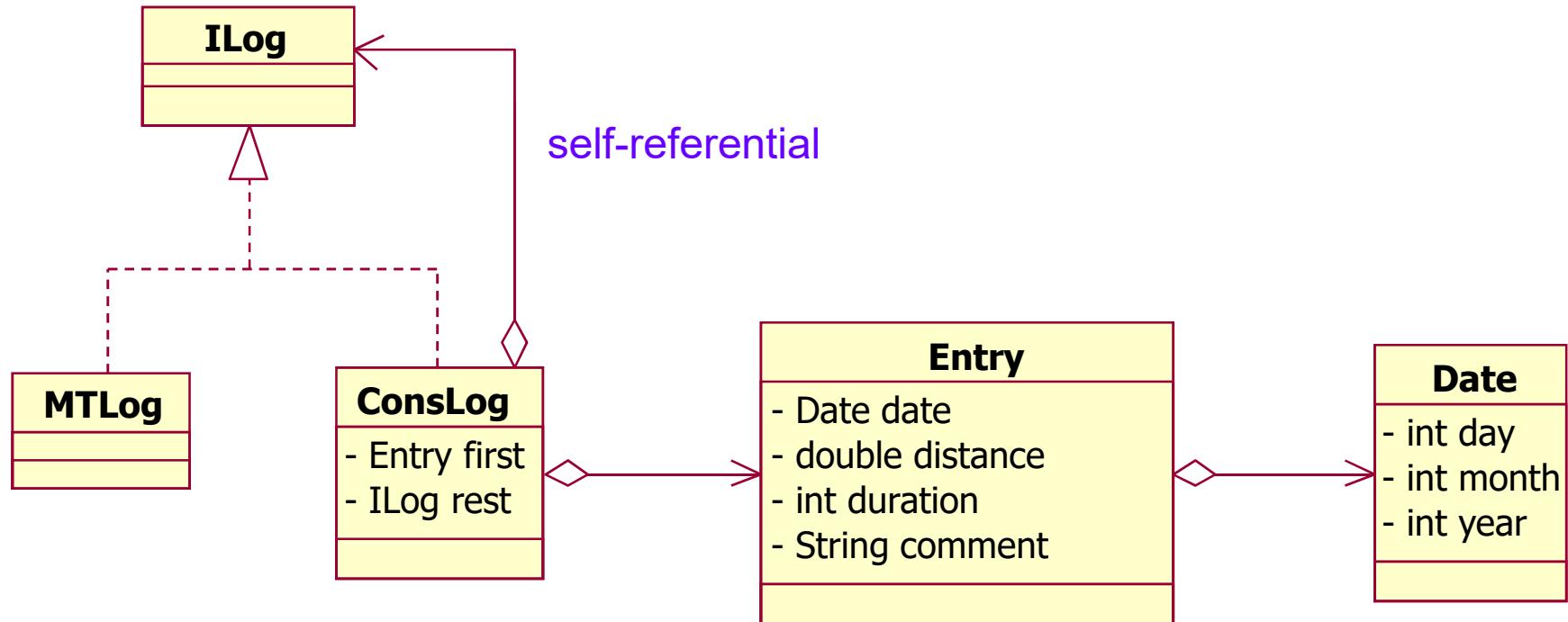
- Develop a program that manages a runner's training log. Every day the runner enters one entry concerning the day's run. Each entry includes the day's date, the distance of the day's run, the duration of the run, and a comment describing the runner's post-run disposition.
- Naturally the program shouldn't just deal with a single log entry but **sequences of log entries**.



Data definition

- The class of Logs is a union:
 - **ILog**, which is the type of all logs;
 - **MTLog**, which represents an empty log; and
 - **ConsLog**, which represents the construction of a new log from an entry and an existing log.

Class diagram



Define classes and constructors

```
public interface ILog {  
}
```

```
public class MTLog implements ILog {  
}
```

```
public class ConsLog implements ILog {  
    private Entry first;  
    private ILog rest;  
    public ConsLog(Entry first, ILog rest) {  
        this.first = first;  
        this.rest = rest;  
    }  
}
```

Define classes and constructors

```
public class Entry {  
    private Date date;  
    private double distance;  
    private int duration;  
    private String comment;  
    public Entry(Date date, double distance,  
                int duration,  
                String comment) {  
        this.date = date;  
        this.distance = distance;  
        this.duration = duration;  
        this.comment = comment;  
    }  
}
```

Define classes and constructors

```
public class Date {  
    private int day;  
    private int month;  
    private int year;  
    public Date(int day, int month, int year) {  
        this.day = day;  
        this.month = month;  
        this.year = year;  
    }  
}
```

Test Constructor

```
public class LogTest extends TestCase {  
    public void testConstructor() {  
        Entry e1 =  
            new Entry(new Date(5, 5, 2005), 5.0, 25, "Good");  
        Entry e2 =  
            new Entry(new Date(6, 6, 2005), 3.0, 24, "Tired");  
        Entry e3 =  
            new Entry(new Date(23, 6, 2005), 26.0, 156, "Great");  
  
        ILog empty = new MTLog();  
        ILog l1 = new ConsLog(e3, empty);  
        ILog l2 = new ConsLog(e2, l1);  
        ILog l3 = new ConsLog(e1, l2);  
        System.out.println(l3);  
  
        ILog all = new ConsLog(e1, new ConsLog(e2,  
                                              new ConsLog(e3, new MTLog()))));  
        assertEquals(l3, all);  
    }  
}
```

toString() method

```
// inside of MTLog class  
public String toString() {  
    return "";  
}
```

```
// inside of ConsLog class  
public String toString() {  
    return this.first.toString() + "\n" + this.rest.toString();  
}
```

```
// inside of Entry class  
public String toString() {  
    return "date: " + this.date.toString()  
        + ", distance: " + this.distance  
        + ", duration: " + this.duration  
        + ", comment: " + this.comment;  
}
```

```
// inside of Date class  
public String toString() {  
    return this.day + "/" + this.month + "/" + this.year;  
}
```

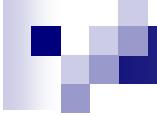
equals() method

```
// in MTLog class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof MTLog))
        return false;
    return true;
}
```

```
// inside ConsLog class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof ConsLog))
        return false;
    else {
        ConsLog that = (ConsLog) obj;
        return this.first.equals(that.first)
            && this.rest.equals(that.rest);
    }
}
```

```
// in Entry class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof Entry))
        return false;
    else {
        Entry that = (Entry) obj;
        return this.date.equals(that.date) &&
               this.distance == that.distance &&
               this.durationInMinutes == that.durationInMinutes &&
               this.postRunFeeling.equals(that.postRunFeeling);
    }
}
```

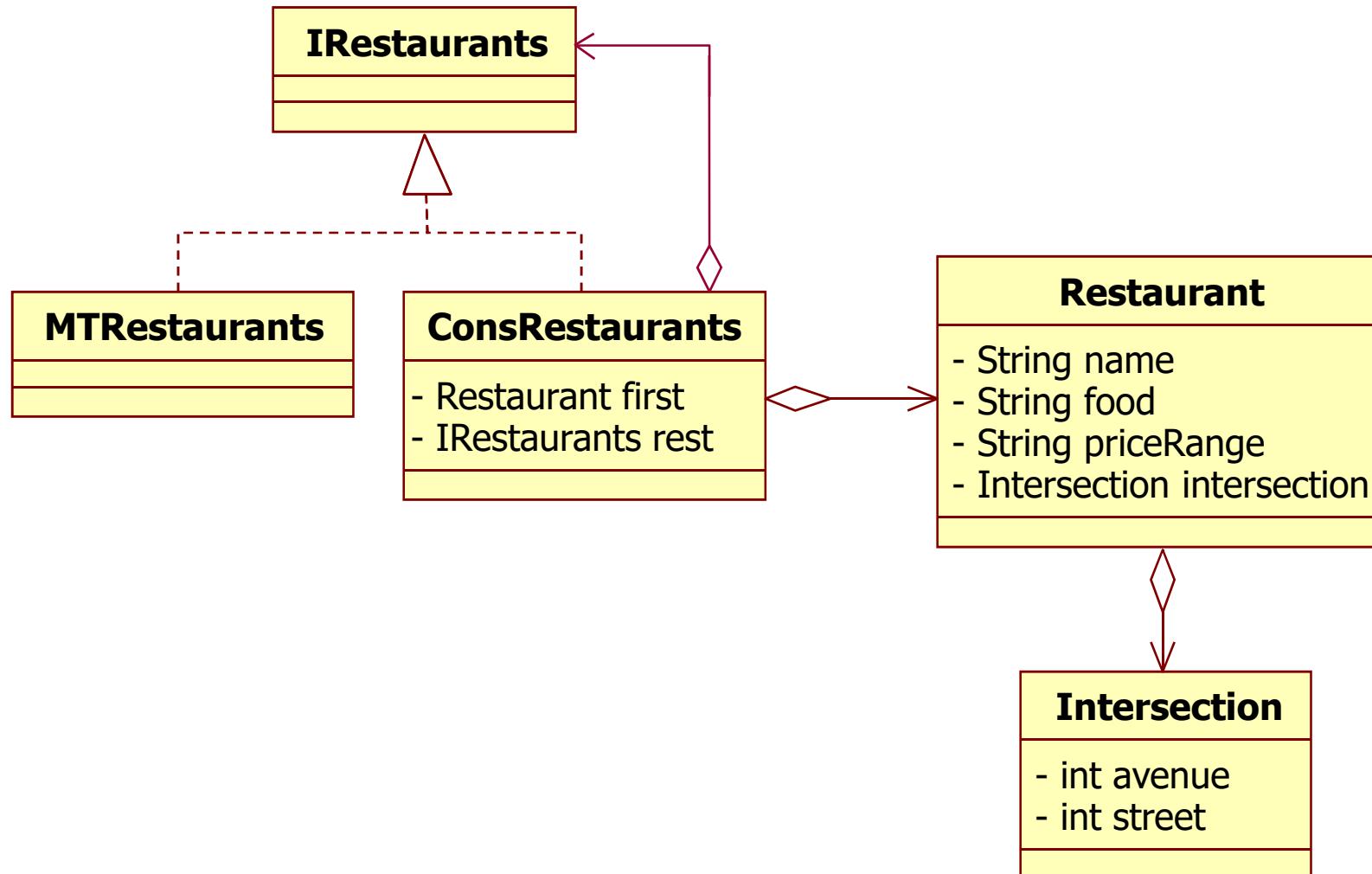
```
// inside Date class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof Date))
        return false;
    else {
        Date that = (Date) obj;
        return this.day == that.day &&
               this.month == that.month &&
               this.year == that.year;
    }
}
```



Recall restaurant example

- Develop a program that helps a visitor navigate Manhattan's restaurant scene. The program must be able to provide four pieces of information for each restaurant: its **name**, the **kind of food** it serves, its **price range**, and the **closest intersection (street and avenue)**.
- Clearly, the visitor assistant should deal with **lists of restaurants**, not just individual restaurants. A visitor may, for example, wish to learn about all Chinese restaurants in a certain area or all German restaurants in a certain price range.

Class diagram



Define classes and constructors

```
public interface IRestaurants {  
}
```

```
public class MTRestaurants implements IRestaurants {  
}
```

```
public class ConsRestaurants implements IRestaurants {  
    private Restaurant first;  
    private IRestaurants rest;  
    public ConsRestaurants(Restaurant first,  
                          IRestaurants rest) {  
        this.first = first;  
        this.rest = rest;  
    }  
}
```

Define Restaurant class

```
public class Restaurant {  
    private String name;  
    private String food;  
    private String priceRange;  
    private Intersection intersection;  
    public Restaurant(String name, String food,  
                      String priceRange,  
                      Intersection intersection) {  
        this.name = name;  
        this.food = food;  
        this.priceRange = priceRange;  
        this.intersection = intersection;  
    }  
}
```

Define Intersection class

```
public class Intersection {  
    private int avenue;  
    private int street;  
  
    public Intersection(int avenue, int street) {  
        this.avenue = avenue;  
        this.street = street;  
    }  
}
```

toString() method

```
// in class ConsRestaurants
public String toString() {
    return this.first.toString() + "\n" + this.rest.toString();
}
```

```
// in class MTRestaurants
public String toString() {
    return "";
}
```

```
// in class Restaurant
public String toString() {
    return "Name: " + this.name + ", food: " + this.food
        + ", range price: " + this.priceRange
        + ", intersection: " + this.intersection.toString() + "\n"
        + this.rest;
}
```

```
// in class Intersection
public String toString() {
    return "avenue: " + this.avenue
        + ", street: " + this.street;
}
```

equals() method

```
// in MTRestaurants class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof MTRestaurants))
        return false;
    return true;
}
```

```
// inside ConsRestaurants class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof ConsRestaurants))
        return false;
    else {
        ConsRestaurants that = (ConsRestaurants) obj;
        return this.first.equals(that.first)
            && this.rest.equals(that.rest);
    }
}
```

```
// in Restaurants class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof Restaurant))
        return false;
    else {
        Restaurant that = (Restaurant) obj;
        return this.name.equals(that.name) &&
            this.food.equals(that.food) &&
            this.priceRange.equals(that.priceRange) &&
            this.intersection.equals(that.intersection);
    }
}
```

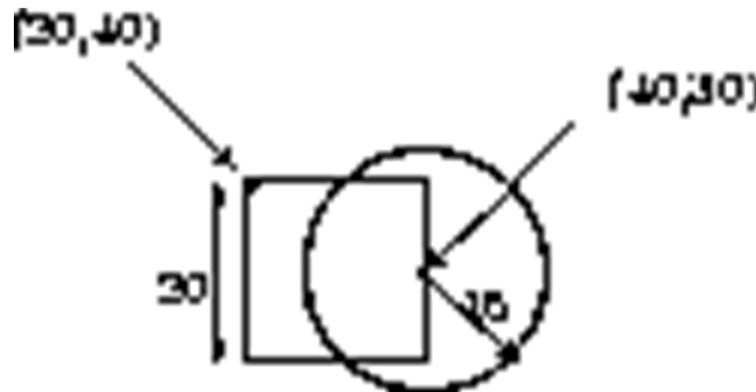
```
// inside Intersection class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof Intersection))
        return false;
    else {
        Intersection that = (Intersection) obj;
        return this.avenue == that.avenue &&
            this.street == that.street;
    }
}
```

Test Constructor

```
public class LoRestaurantsTest extends TestCase {  
    public void testConstructor() {  
        Restaurant r1 = new Restaurant("Chez Nous",  
            "French", "exp.", new Intersection(7, 65));  
        Restaurant r2 = new Restaurant("Das Bier",  
            "German", "cheap", new Intersection(2, 86));  
        Restaurant r3 = new Restaurant("Sun",  
            "Chinese", "cheap", new Intersection(10, 13));  
  
        IRestaurants empty = new MTRestaurants();  
        IRestaurants l1 = new ConsRestaurants(r3, empty);  
        IRestaurants l2 = new ConsRestaurants(r2, l1);  
        IRestaurants l3 = new ConsRestaurants(r1, l2);  
        System.out.println(l3);  
  
        IRestaurants all = new ConsRestaurants(r1,  
            new ConsRestaurants (r2,  
                new ConsRestaurants(r3, new MTRestaurants()))));  
        assertEquals(all, l3);  
    }  
}
```

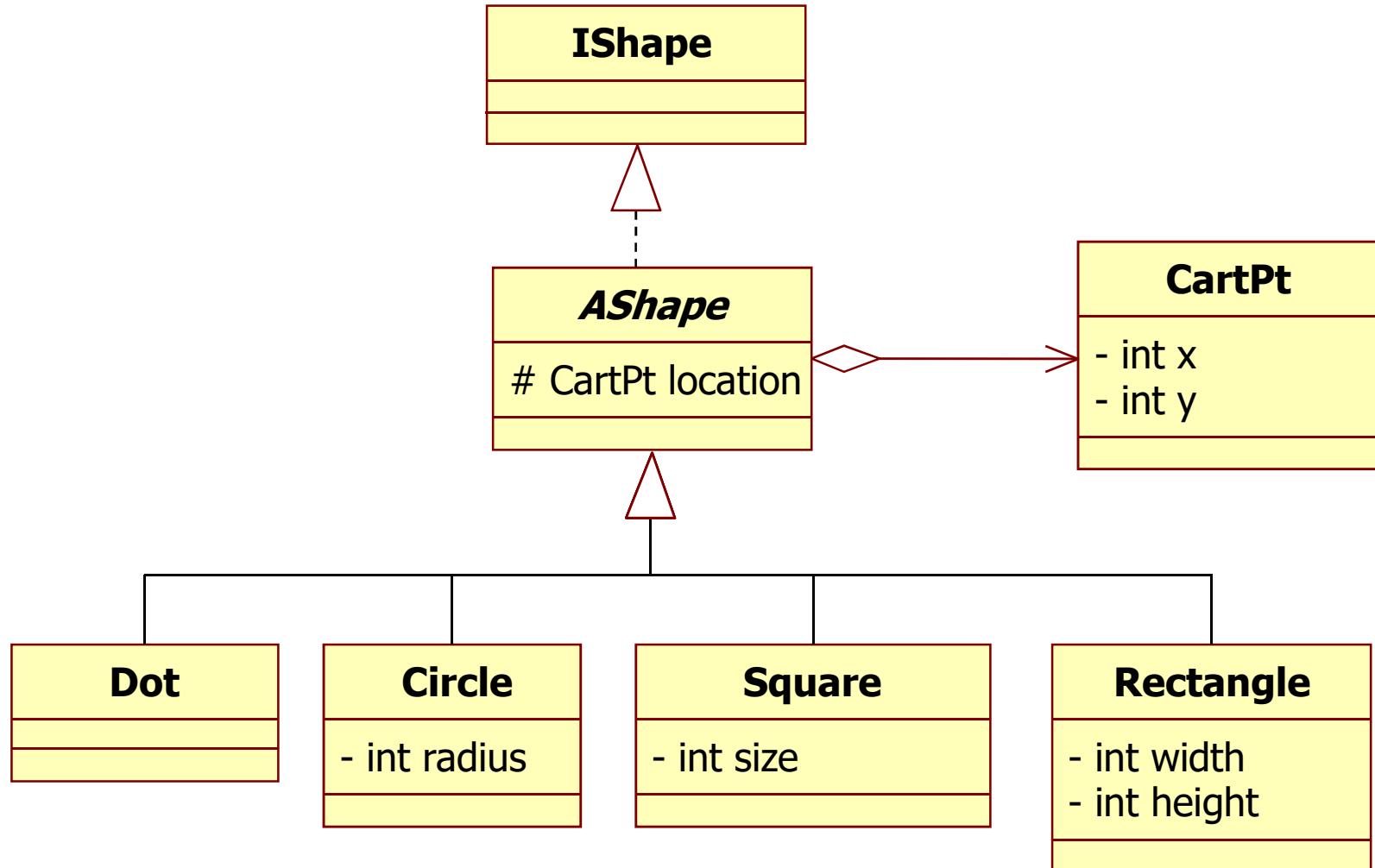
Overlaying shape example

- Develop a drawing program that deals with at least three kinds of shapes: dots, squares, and circles. In addition, the program should also deal with **overlaying shapes** on each other. In the following figure, for example, we have superimposed a circle on the right side of a square:

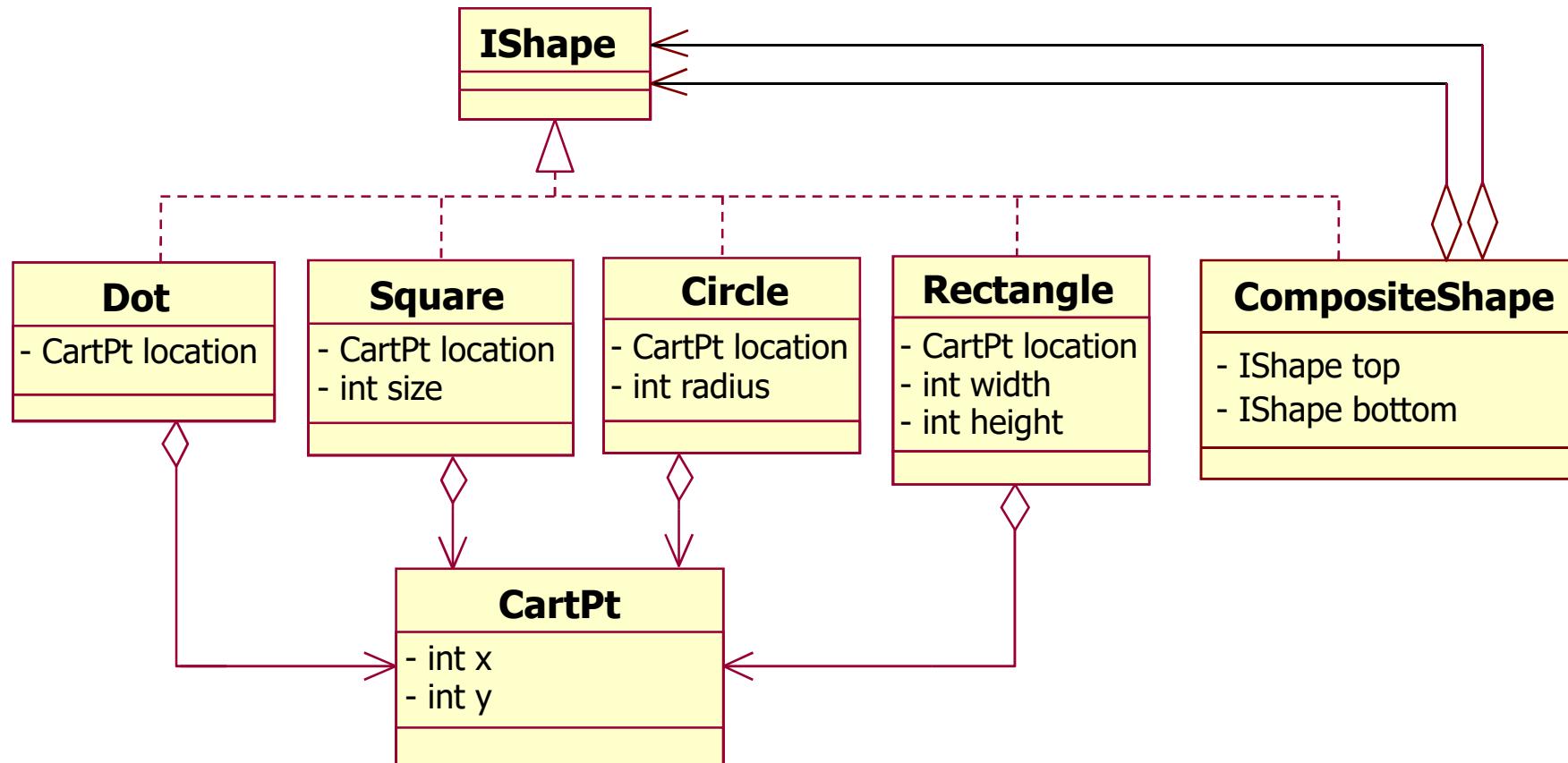


- We could now also superimpose this compounded shape on another shape and so on.

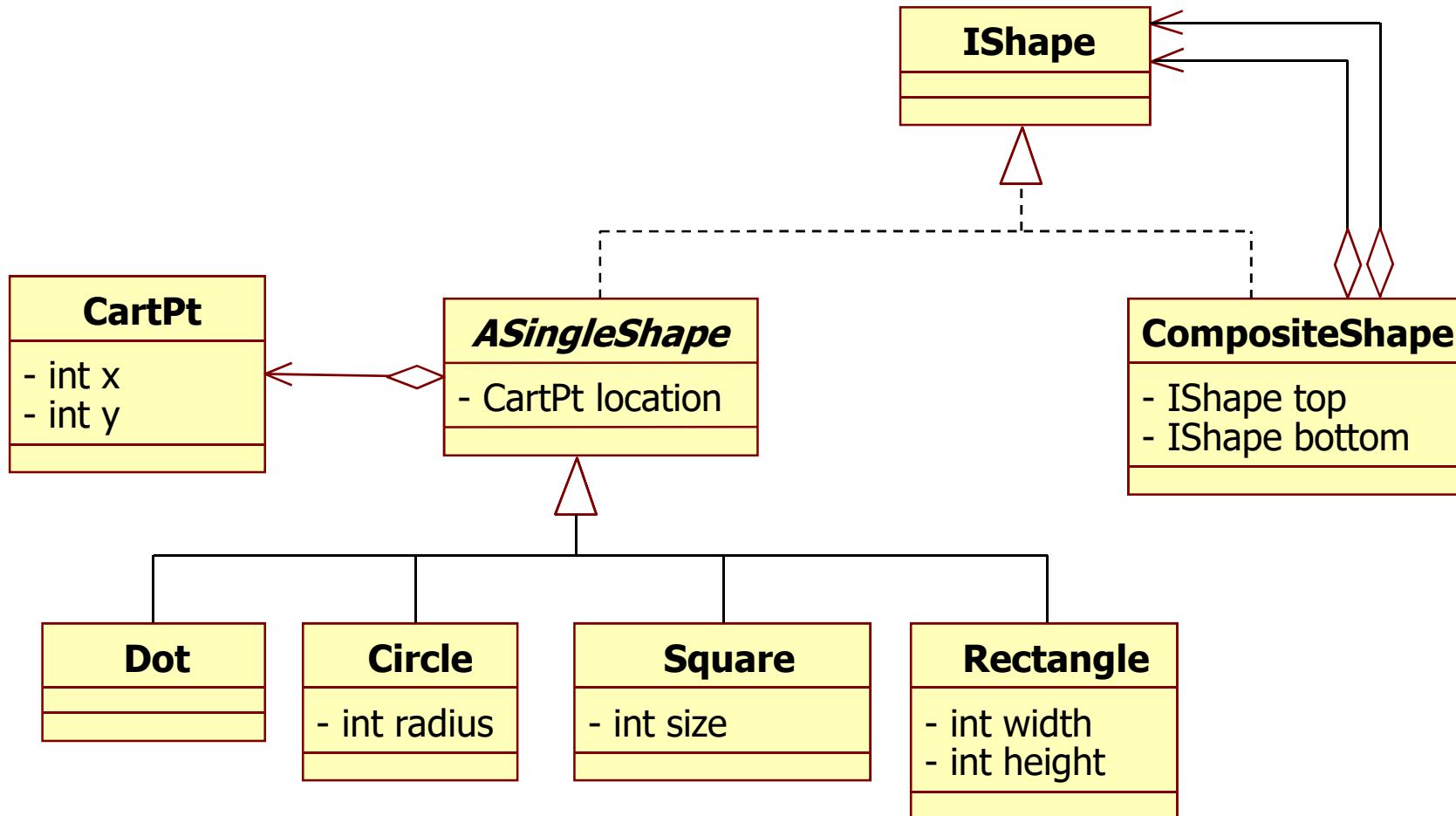
Old class design



New design after add Composite Shape



New design after add Composite Shape



Define classes and constructors

```
public interface IShape {  
}
```

```
public class CompositeShape implements IShape {  
    private IShape top;  
    private IShape bottom;  
    public CompositeShape(IShape top, IShape bottom) {  
        this.top = top;  
        this.bottom = bottom;  
    }  
}
```

```
public abstract class ASingleShape implements IShape {  
    protected CartPt location;  
    public ASingleShape(CartPt location) {  
        this.location = location;  
    }  
}
```

Define classes and constructors

```
public class Square extends ASingleShape {  
    private int size;  
    public Square(CartPt location, int size){  
        super(location);  
        this.size = size;  
    }  
}
```

```
public class Circle extends ASingleShape {  
    private int radius;  
    public Circle(CartPt location, int radius) {  
        super(location);  
        this.radius = radius;  
    }  
}
```

```
public class Dot extends ASingleShape {  
    public Dot(CartPt location) {  
        super(location);  
    }  
}
```

Define classes and constructors

```
public class Rectangle extends ASingleShape {  
    private int width;  
    private int height;  
    public Rectangle(CartPt location, int width, int height) {  
        super(location);  
        this.width = width;  
        this.height = height;  
    }  
}
```

```
public class CartPt {  
    private int x;  
    private int y;  
    public CartPt(int x, int y){  
        this.x = x;  
        this.y = y;  
    }  
}
```

Test Constructor

```
public class ShapeTest extends TestCase {  
    public void testConstructor() {  
        IShape s1 = new Square(new CartPt(4, 3), 40);  
        IShape s2 = new Square(new CartPt(3, 4), 50);  
        IShape c1 = new Circle(new CartPt(0, 0), 20);  
        IShape c2 = new Circle(new CartPt(12, 5), 20);  
  
        IShape u1 = new CompositeShape(s1, s2);  
        IShape u2 = new CompositeShape(s1, c2);  
        IShape u3 = new CompositeShape(c1, u1);  
        IShape u4 = new CompositeShape(u3, u2);  
        IShape u5 = new CompositeShape(s1,  
                                         new Compositeshape(c1, s2));  
        System.out.println(u5);  
    }  
}
```

toString() method

```
// in class CompositeShape  
public String toString() {  
    return this.top.toString() + "\n" + this.bottom.toString();  
}
```

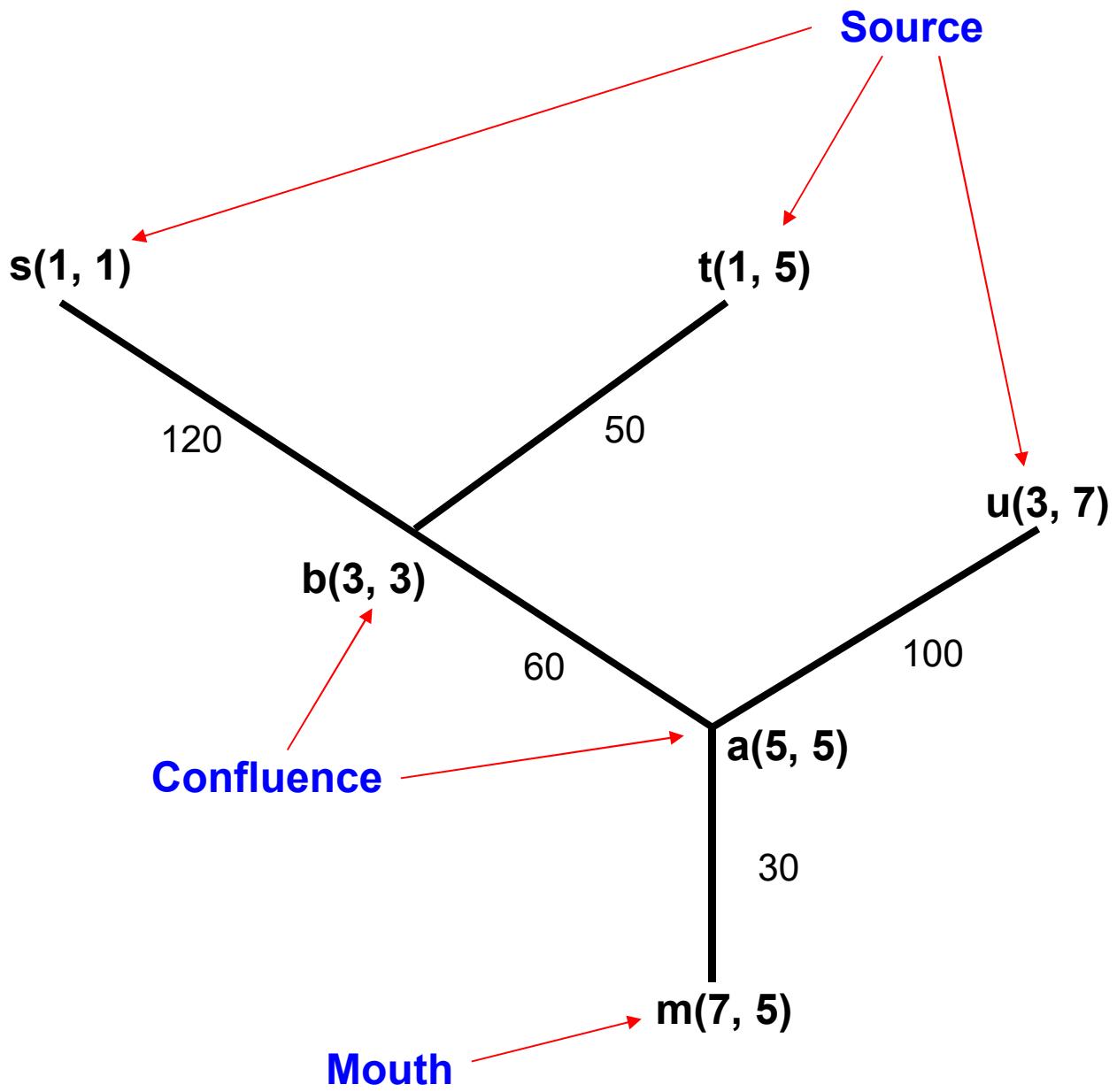
```
// in class ASingleShape  
public String toString() {  
    return "Location: " + this.location.toString();  
}
```

```
// in class Square  
public String toString() {  
    return super.toString() + "Size: " + this.size;  
}
```

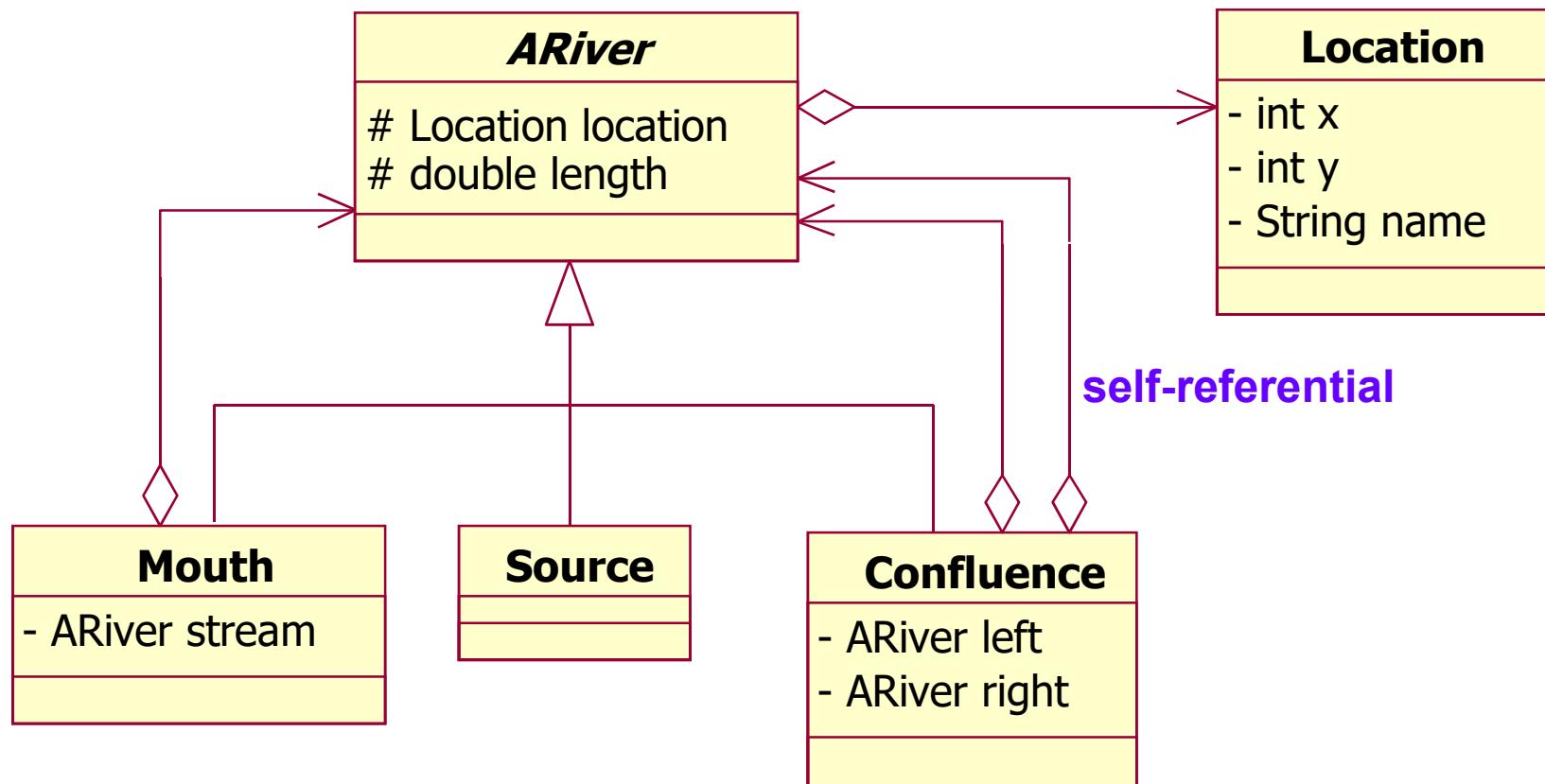
```
// in class CartPt  
public String toString() {  
    return "(" + this.x + ", " + this.y + ")";  
}
```

River Systems Example

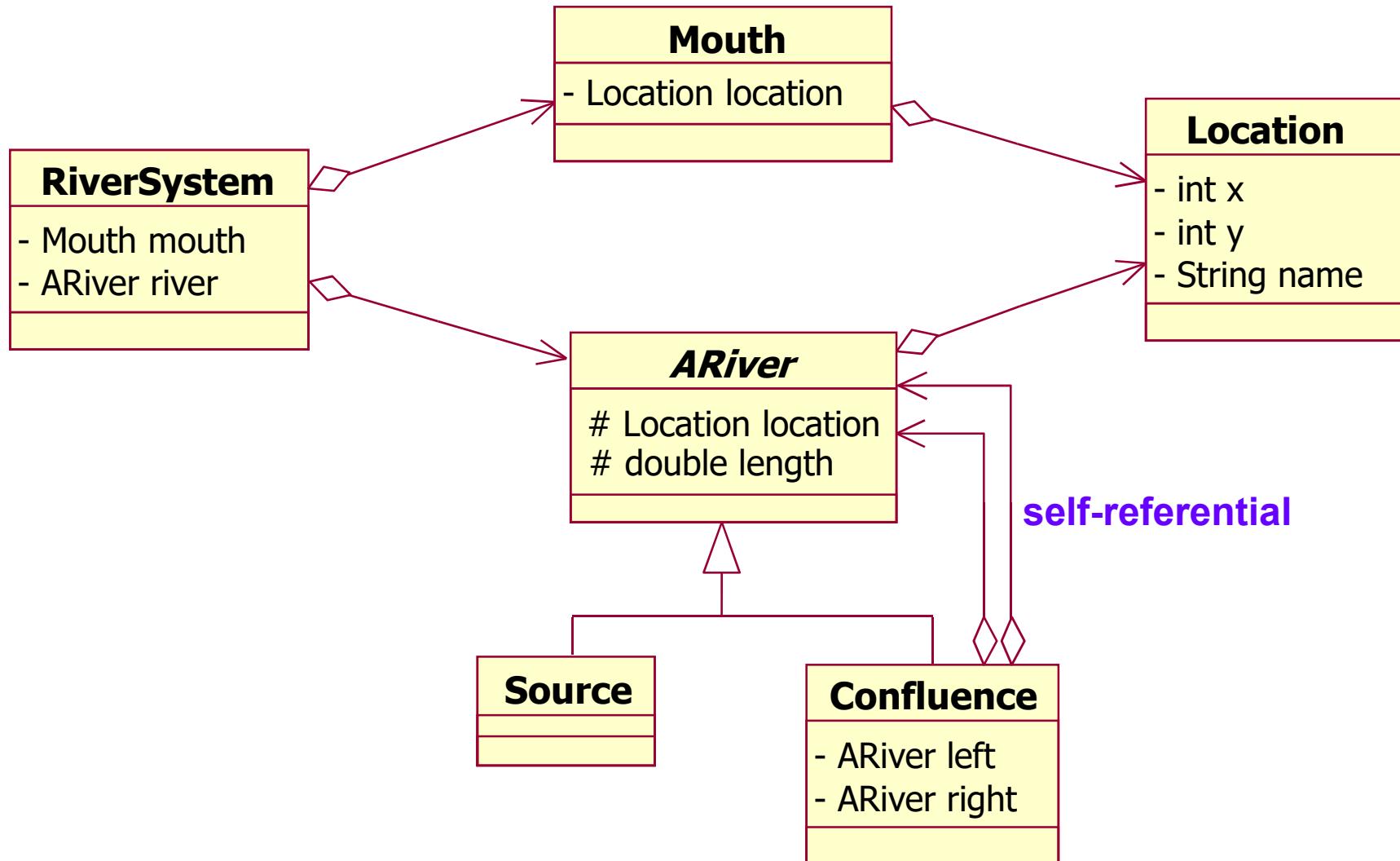
- The environmental protection agency monitors the water quality for river systems.
- A river system consists of a source of river, its tributaries (nhánh sông), the tributaries of the tributaries, and so on. Besides, each of part in the river system has location, and its length.
- The place where a tributary flows into a river is called confluence (hợp dòng).
- The initial river segment is its source (nguồn)
- The river's end - the segment that ends in a sea or another river - is called its mouth (cửa sông)



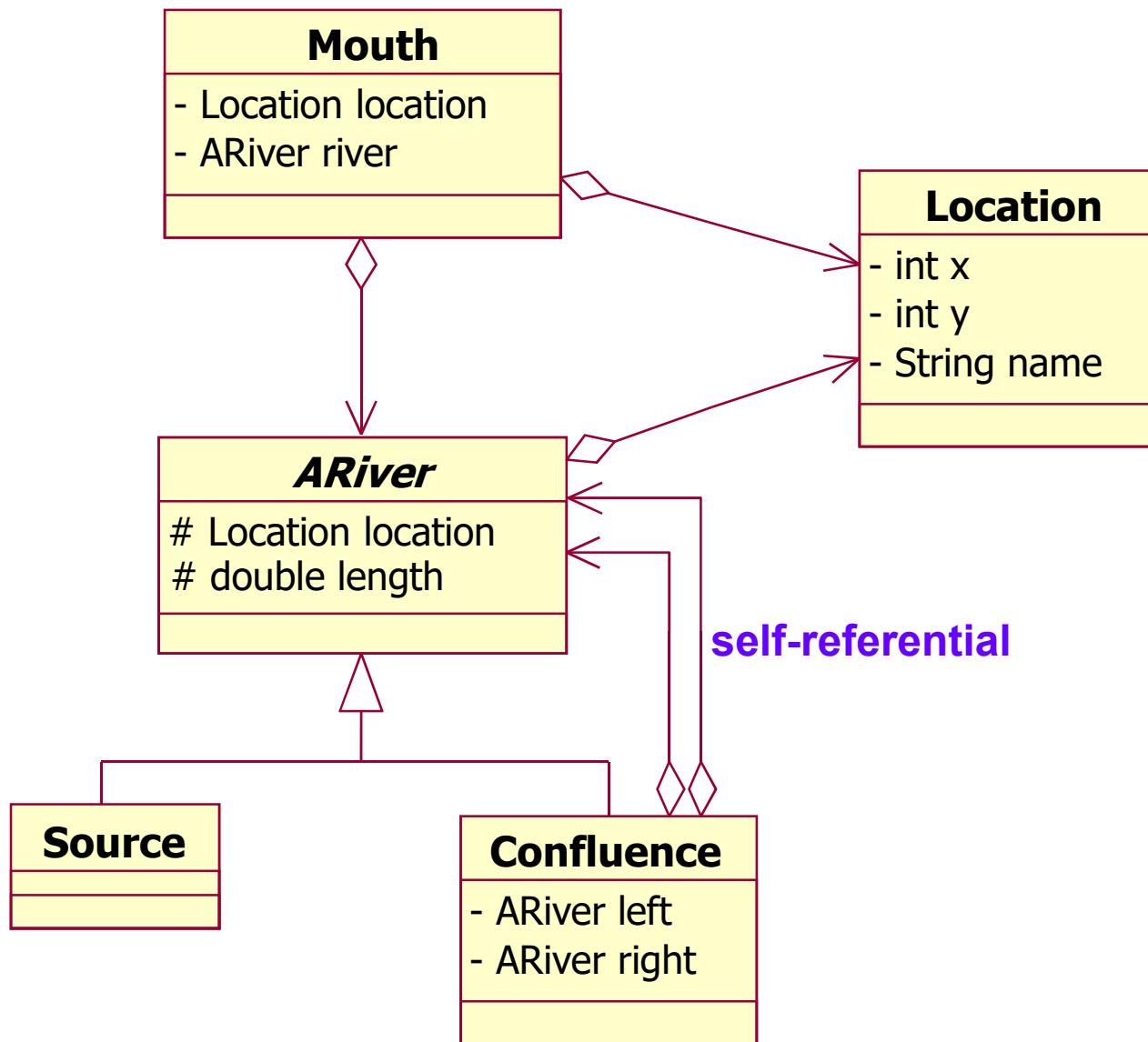
Class Diagram (design 1)



Class diagram (design 2)



Class diagram (design 3)



Define classes and constructors

```
public class Location {  
    private int x;  
    private int y;  
    private String name;  
    public Location(int x, int y, String name) {  
        this.x = x;  
        this.y = y;  
        this.name = name;  
    }  
}
```

```
public class Mouth {  
    private Location location;  
    private ARiver river;  
    public Mouth(Location location, ARiver river) {  
        this.location = location;  
        this.river = river;  
    }  
}
```

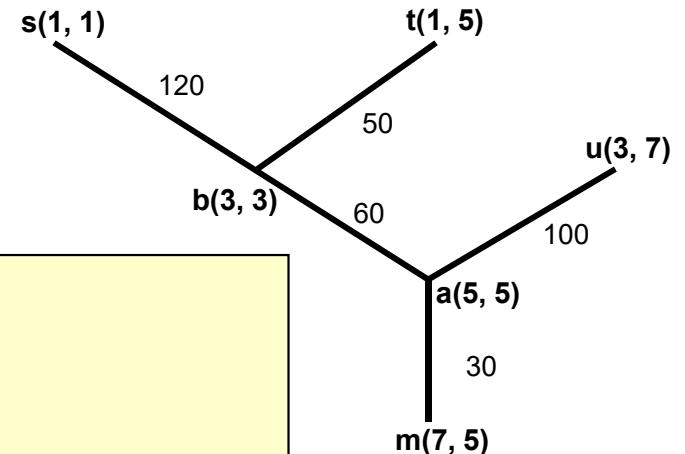
```
public abstract class ARiver {  
    protected Location location;  
    protected double length;  
    public ARiver(Location location, double length) {  
        this.location = location;  
        this.length = length;  
    }  
}
```

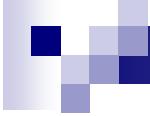
```
public class Source extends ARiver {  
    public Source(Location location, double length) {  
        super(location,length);  
    }  
}
```

```
public class Confluence extends ARiver {  
    private ARiver left;  
    private ARiver right;  
    public Confluence(Location location, double length,  
                      ARiver left, ARiver right) {  
        super(location,length);  
        this.left = left;  
        this.right = right;  
    }  
}
```

Test Constructor

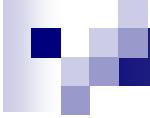
```
public class ARiverTest extends TestCase {  
    public void testConstructor() {  
        ARiver s = new Source(  
            new Location(1, 1, "s"), 120.0);  
        ARiver t = new Source(  
            new Location(1, 5, "t"), 50.0);  
        ARiver u = new Source(  
            new Location(3, 7, "u"), 100.0);  
  
        ARiver b = new Confluence(  
            new Location(3, 3, "b"), 60.0, s, t);  
        ARiver a = new Confluence(  
            new Location(5, 5, "a"), 30.0, b, u);  
  
        Mouth m = new Mouth(new Location(7, 5, "m"), a);  
    }  
}
```





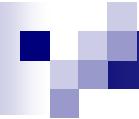
Exercises 5.1

- Develop a program that assists real estate agents.
The program deals with listings of available houses
 - Make examples of listings.
Develop a data definition for listings of houses.
 - Implement the definition with classes.
Translate the examples into objects



Exercises 5.2

- Design a program that assists a bookstore manager with reading lists for local schools. . .
 - Develop a class diagram for a list of books (by hand). Translate the diagram into classes.
 - Create two lists of books that contain at least one of the your favorite books



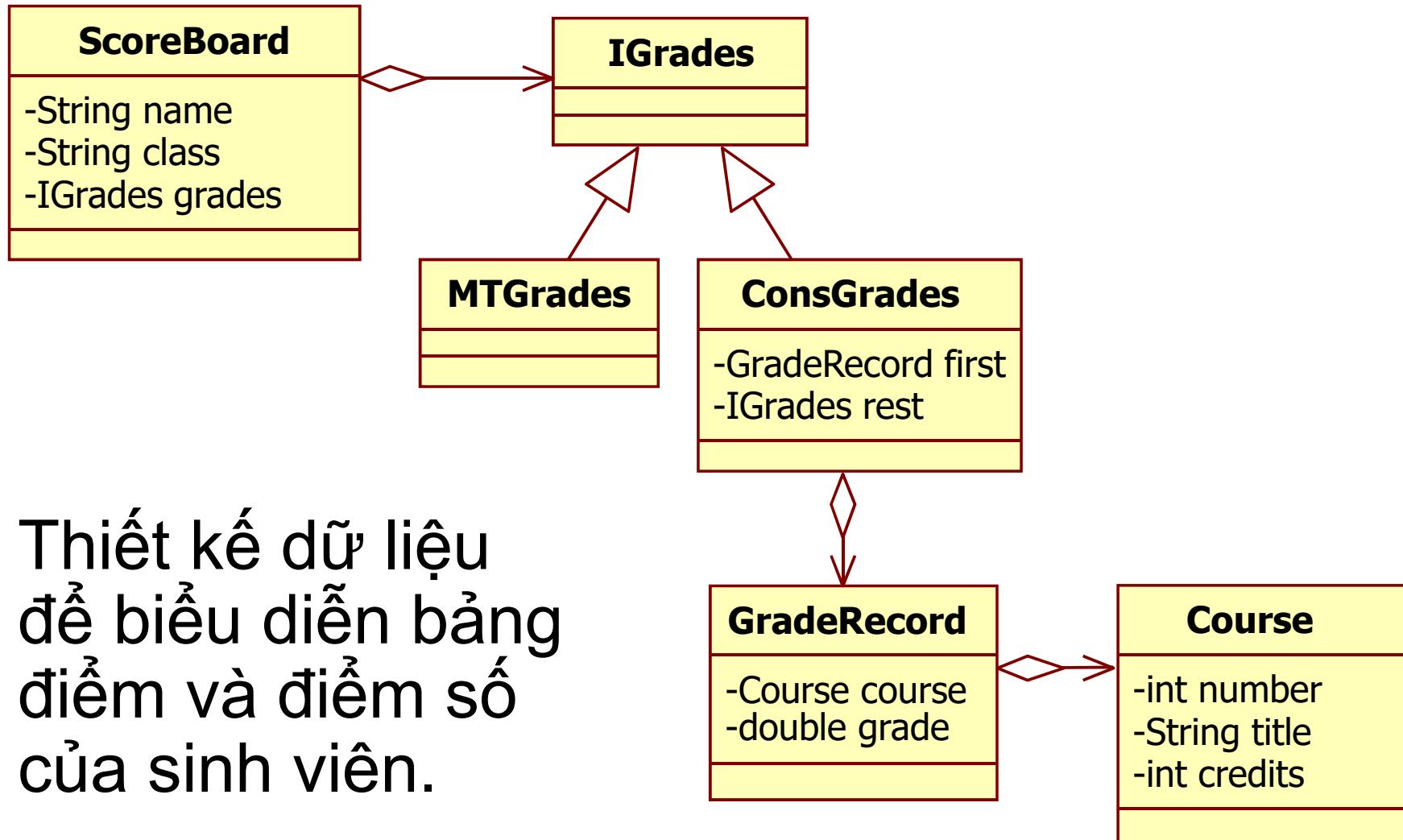
Exercise 5.3

- Research the tributaries of your favorite river. Create a data representation of the river and its tributaries.
Draw the river system as a schematic diagram.
- Modify the classes that represent river segments, mouths, and sources so that you can add the names of these pieces to your data representation.
Can you think of a river system that needs names for all three segments involved in a confluence?
Represent such a confluence with the revised classes.

Exercises 5.4

- Thông tin về điểm số của mỗi sinh viên được cho trong một bảng điểm. Mỗi bảng điểm (**ScoreBoard**) bao gồm tên sinh viên (**name**), khóa học (**class**), và một danh sách điểm số các môn học của sinh viên. Thông tin về điểm số (**GradeRecord**) của sinh viên bao gồm mã số môn học (**number**), tên môn học (**title**), số tín chỉ (**credits**) và điểm số (**grade**).
 - Ví dụ: một bảng điểm của sinh viên **Tran Van Hoa**, khóa **2009** gồm các mục điểm số:
 - 211, "Database Fundamentals", 3, 7.5
 - 220, "Basic Programming", 2, 5.0
 - 690, "Algorithms", 4, 7.0
 - 721, "Data Structure", 4, 8.0

ScoreBoard class diagram



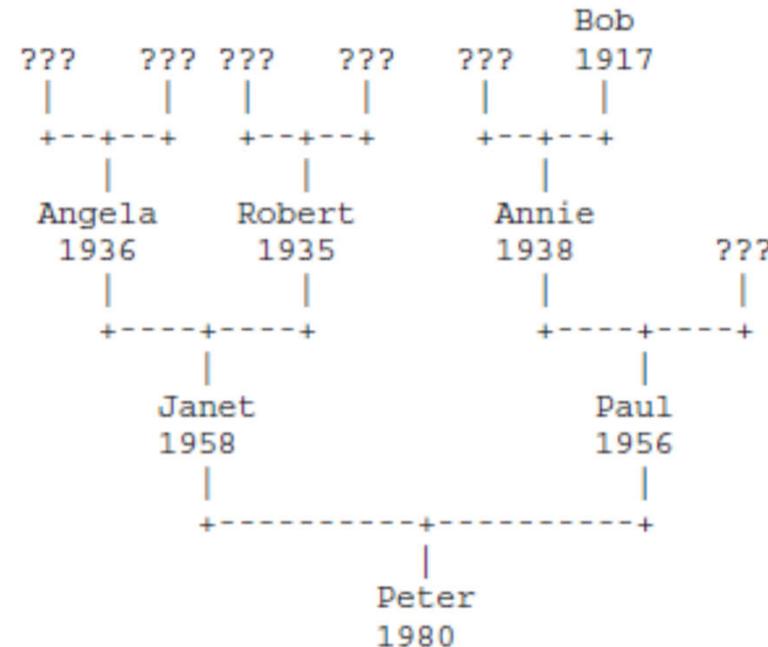
Exercises 5.5

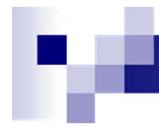
... Develop a program that helps with recording a person's ancestor tree.

Specifically, for each person we wish to remember the person's **name** and **year of birth**, in addition to the ancestry on the **father's** and the **mother's** side, if it is available.

The tree on the left is an example; the nodes with “???” indicate where the genealogist couldn't find any information.

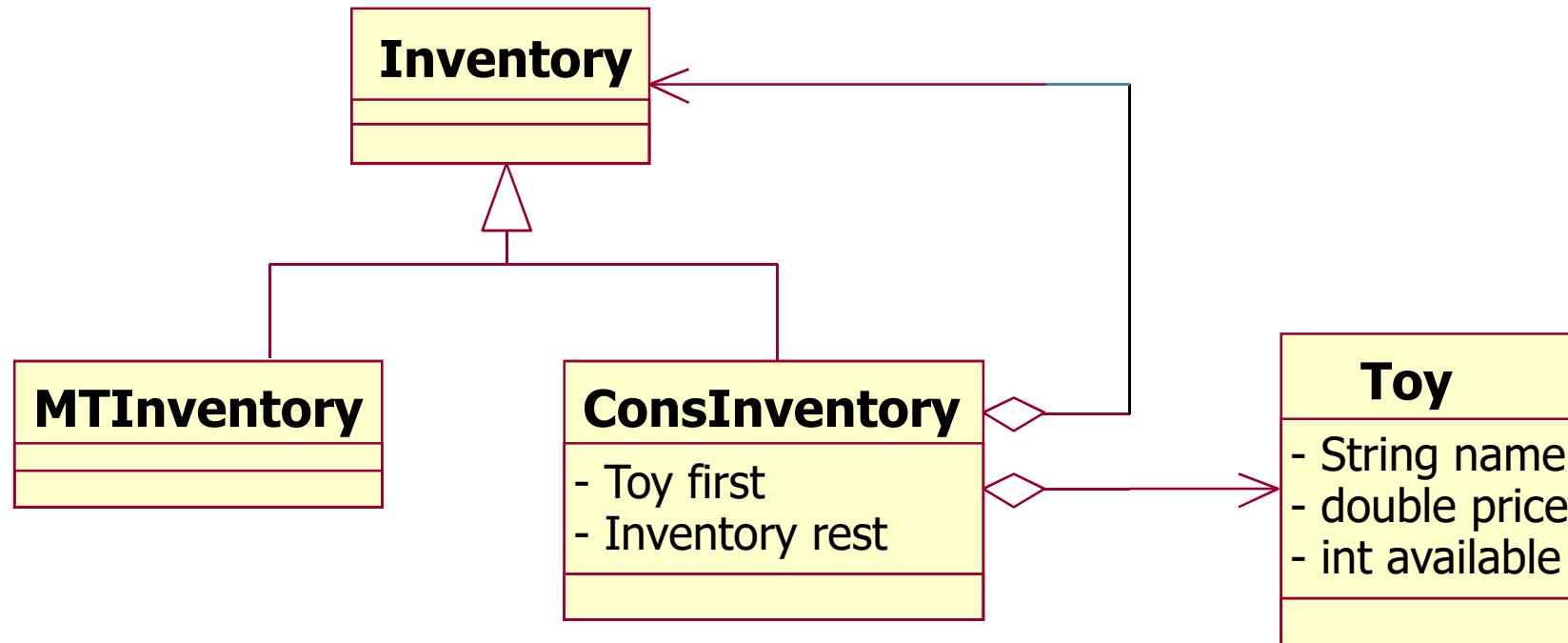
- ... Develop the class diagram (by hand) and the class definitions to represent ancestor family trees. Then translate the sample tree into an object.
- Also draw your family's ancestor tree as far as known and represent it as an object.





Part 2: Methods and Classes with Mutual References

Recall Inventory problem

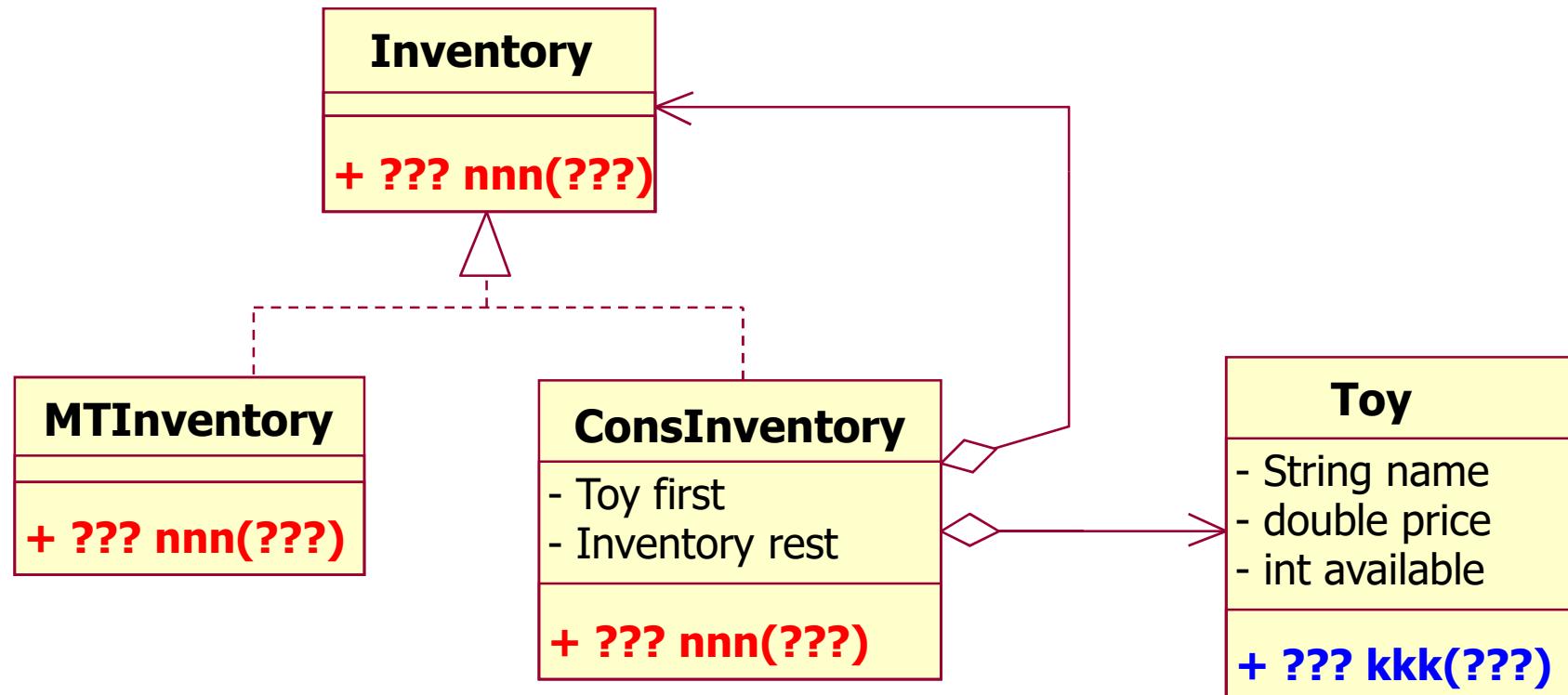


Class diagram

Recall Inventory problem

- Develop the method **contains**, which determines whether or not the name of toy occurs in the Inventory
- Develop the method **isBelow**, which checks whether all of the prices of toys in inventory are below the threshold.
- Develop the method **howMany**, which produces the number of toys in the inventory.
- Develop the method **raisePrice**, which produces an inventory in which all prices are raised by a **rate 5%** (use **mutable** and **immutable**).

Add methods to the **Inventory**'s Class Diagram



Q: Write Java method templates for all the classes in the class diagram ?

Java template for Toy

```
public class Toy {  
    private String name;  
    private double price;  
    private int available;  
    public Toy(String name, double price, int available) {  
        this.name = name;  
        this.price = price;  
        this.available = available;  
    }  
  
    public ??? kkk(???) {  
        ...this.name...  
        ...this.price...  
        ...this.available...  
    }  
}
```

Java template for Inventory

```
public interface Inventory {  
    public ??? nnn(??);  
}
```

Java template for MTInventory

```
public class MTInventory implements Inventory {  
  
    public MTInventory () { }  
  
    public ??? nnn(??) {  
        ...  
    }  
}
```

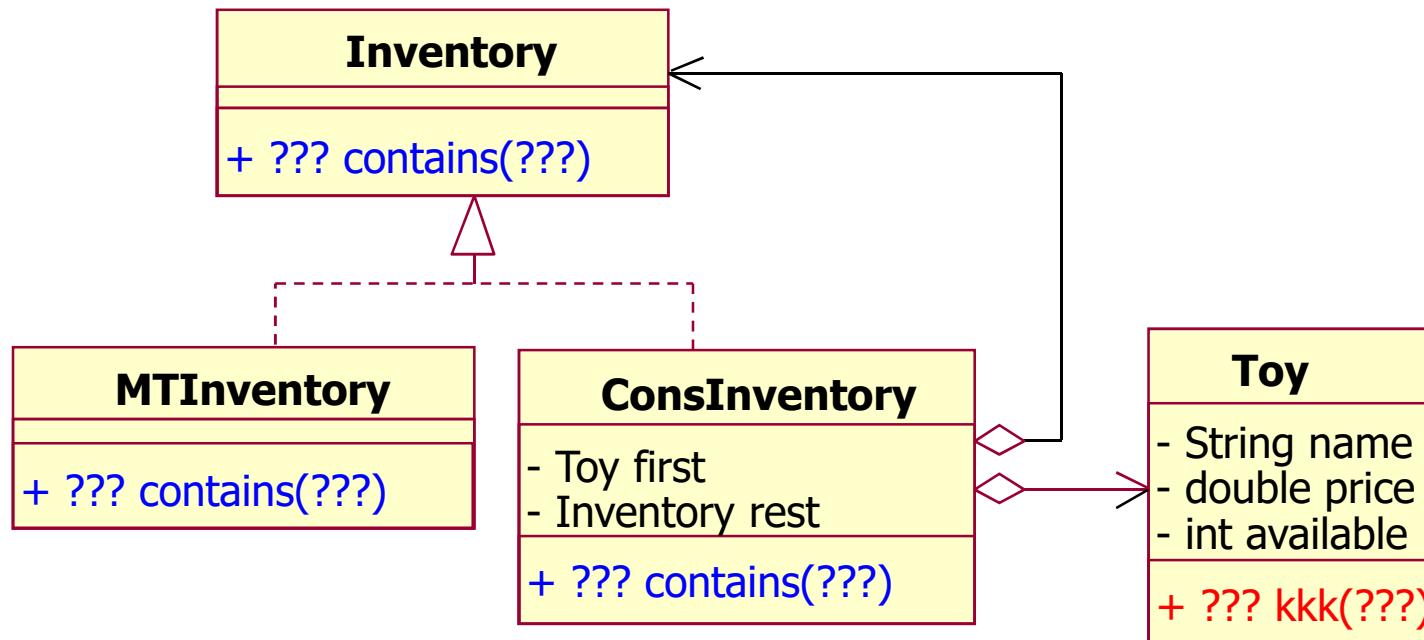
Java template for ConsInventory

```
public class ConsInventory implements Inventory {  
    private Toy first;  
    private Inventory rest;  
    public Cons(Toy first, Inventory rest) {  
        this.first = first;  
        this.rest = rest;  
    }  
  
    public ??? nnn(???) {  
        ...this.first.kkk(???)...  
        ...this.rest.nnn(???)...  
    }  
}
```

Since all instances in the **rest** field are always created from either **MTInventory** or **ConsInventory**, this means that the method call **this.rest.nnn()** really invokes one of the concrete **nnn()** methods in **MTInventory** or **ConsInventory**

Add **contains** method

- Develop the method **contains**, which determines whether or not the name of toy occurs in the Inventory



Purpose and contract of contains() for Inventory

```
public interface Inventory {  
    // determines whether or not the name of  
    // toy occurs in the Inventory  
    public boolean contains(String toyName);  
}
```

Examples to test `contains()`

```
Toy doll = new Toy("doll", 17.95, 5);
Toy robot = new Toy("robot", 22.05, 3);
Toy gun = new Toy ("gun", 15.0, 4);

Inventory empty = new MTInventory();
Inventory i1 = new ConsInventory(doll, empty);
Inventory i2 = new ConsInventory(robot, i1);
Inventory all = new ConsInventory(doll,
                                   new ConsInventory(robot,
                                   new ConsInventory(gun, new MTInventory())));

empty.contains("robot") → should be false
i1.contains("robot") → should be false
i2.contains("robot") → should be true
all.contains("robot") → should be true
all.contains("car") → should be false
```

contains() for MTInventory and ConsInventory

```
//in class MTInventory
public boolean contains(String toyName) {
    return false;
}
```

```
// in class ConsInventory
public boolean contains(String toyName) {
    return this.first.isName(toyName)
        || this.rest.contains(toyName);
}
```

```
//in class Toy
public boolean isName(String toyName) {
    return this.name.equals(toyName);
}
```

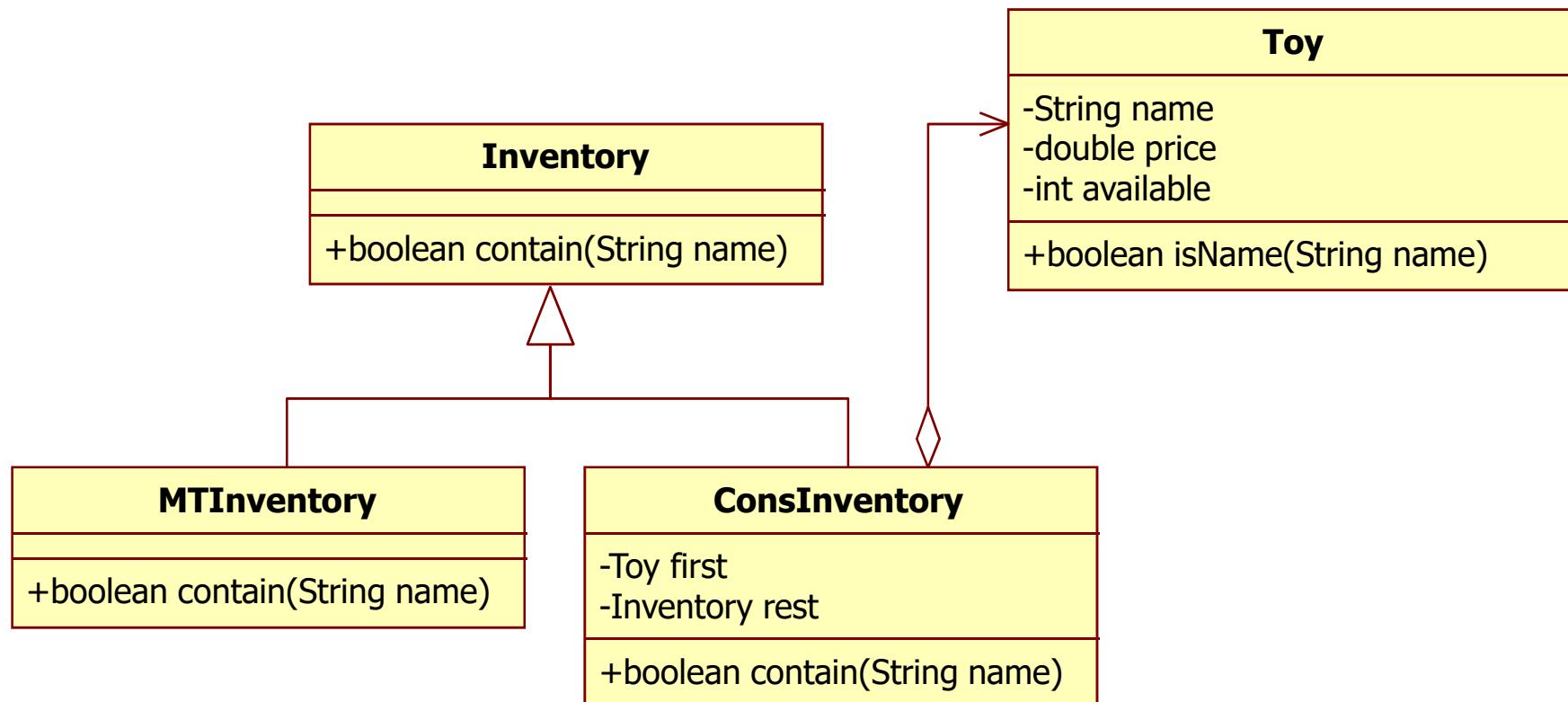
Test contains()

```
public void testContains(){
    Toy doll = new Toy("doll", 17.95, 5);
    Toy robot = new Toy("robot", 22.05, 3);
    Toy gun = new Toy ("gun", 15.0, 4);

    Inventory empty = new MTInventory();
    Inventory i1 = new ConsInventory(doll, empty);
    Inventory i2 = new ConsInventory(robot, i1);
    Inventory all = new ConsInventory(doll,
        new ConsInventory(robot,
            new ConsInventory(gun, new MTInventory())));

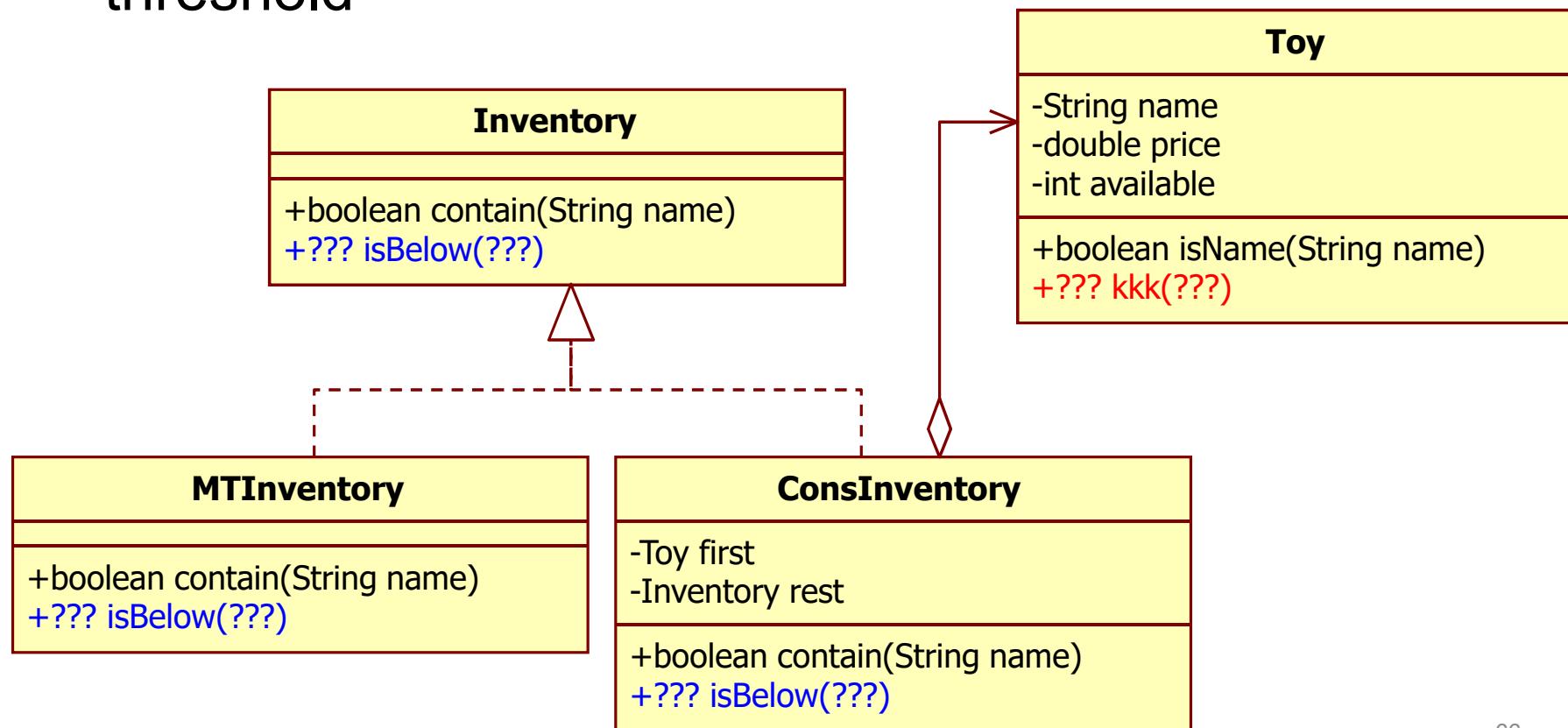
    assertFalse(empty.contains("robot"));
    assertFalse(i1.contains("robot"));
    assertTrue(i2.contains("robot"));
    assertTrue(all.contains("robot"));
    assertFalse(all.contains("car"));
}
```

Class diagram after add contains()



Add **isBelow** method

- Develop the method **isBelow**, which checks whether all of the prices of toys in inventory are below the threshold



Purpose and contract of **isBelow()** for Inventory

```
public interface Inventory {  
    // determines whether or not the name of  
    // toy occurs in the Inventory  
    public boolean contains(String toyName);  
  
    // determines whether or not all prices of toys  
    // in the Inventory below a threshold  
    public boolean isBelow(double threshold);  
}
```

Examples to test `isBelow()`

```
Toy doll = new Toy("doll", 17.95, 5);
Toy robot = new Toy("robot", 22.05, 3);
Toy gun = new Toy ("gun", 15.0, 4);

Inventory empty = new MTInventory();
Inventory i1 = new ConsInventory(doll, empty);
Inventory i2 = new ConsInventory(robot, i1);
Inventory all = new ConsInventory(doll,
                                   new ConsInventory(robot,
                                   new ConsInventory(gun, new MTInventory())));

empty.isBelow(20) → should be true
i1.isBelow(20) → should be true
i2.isBelow(20) → should be false
all.isBelow(20) → should be false
all.isBelow(25) → should be true
```

isBelow() for MTInventory and ConsInventory

```
//inside of MTInventory class
public boolean isBelow(double threshold) {
    return true;
}
```

```
// inside of ConsInventory class
public boolean isBelow(double threshold) {
    return this.first.isPriceBelow(threshold)
        && this.rest.isBelow(threshold);
}
```

```
// inside of Toy class
public boolean isPriceBelow(double threshold) {
    return this.price < threshold;
}
```

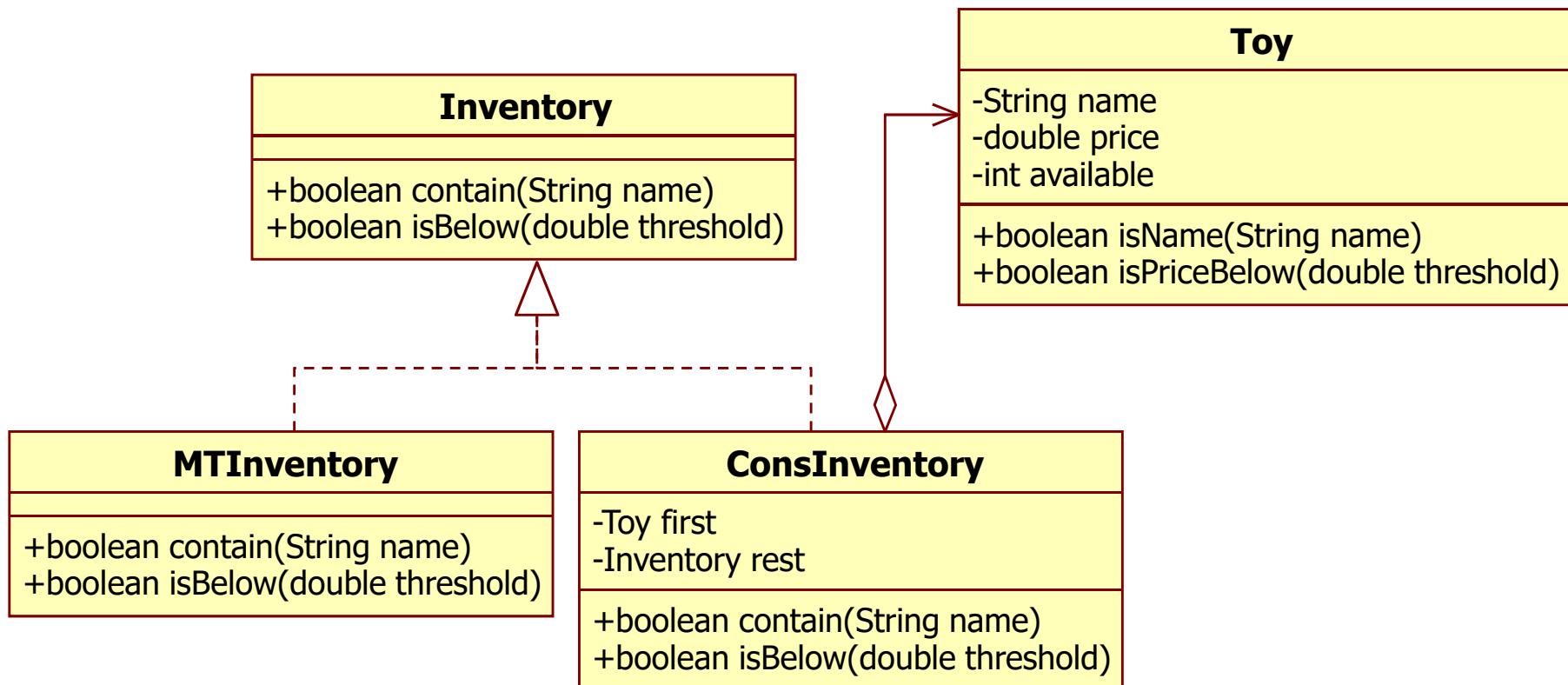
Test `isBelow()`

```
public void testIsBelow(){
    Toy doll = new Toy("doll", 17.95, 5);
    Toy robot = new Toy("robot", 22.05, 3);
    Toy gun = new Toy ("gun", 15.0,4);

    Inventory empty = new MTInventory();
    Inventory i1 = new ConsInventory(doll, empty);
    Inventory i2 = new ConsInventory(robot, i1);
    Inventory all = new ConsInventory(doll,
                                       new ConsInventory(robot,
                                             new ConsInventory(gun, new MTInventory())));

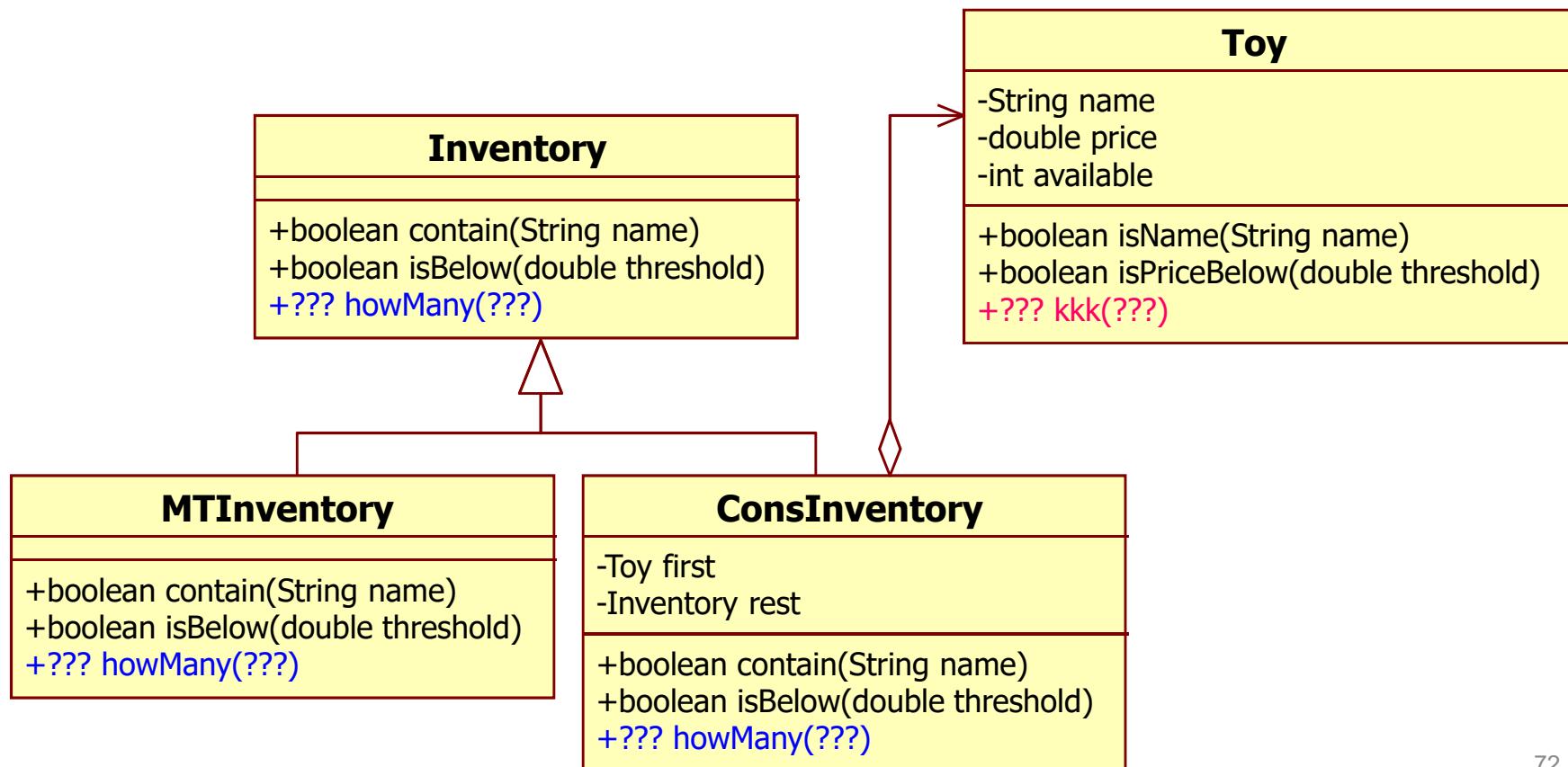
    assertTrue(empty.isbelows(20));
    assertTrue(i1.isBelow(20));
    assertFalse(i2.isBelow(20));
    assertFalse(all.isBelow(20));
    assertTrue(all.isBelow(25));
}
```

Class diagram after add isBelow()



Add **howMany** method

- Develop the method **howMany**, which produces the number of toy items in the inventory.



Purpose and contract of **howMany()** for Inventory

```
public interface Inventory {  
    ...  
    // count the number of items in the Inventory  
    public int howMany();  
}
```

Examples to test `howMany()`

```
Toy doll = new Toy("doll", 17.95, 5);
Toy robot = new Toy("robot", 22.05, 3);
Toy gun = new Toy ("gun", 15.0, 4);

Inventory empty = new MTInventory();
Inventory i1 = new ConsInventory(doll, empty);
Inventory i2 = new ConsInventory(robot, i1);
Inventory all = new ConsInventory(doll,
                                   new ConsInventory(robot,
                                   new ConsInventory(gun, new MTInventory())));

empty.howMany() → should be 0
i1.howMany() → should be 1
i2.howMany() → should be 2
all.howMany() → should be 3
```

howMany() for MTInventory and ConsInventory

```
// inside of MTInventory class
public int howMany() {
    return 0;
}
```

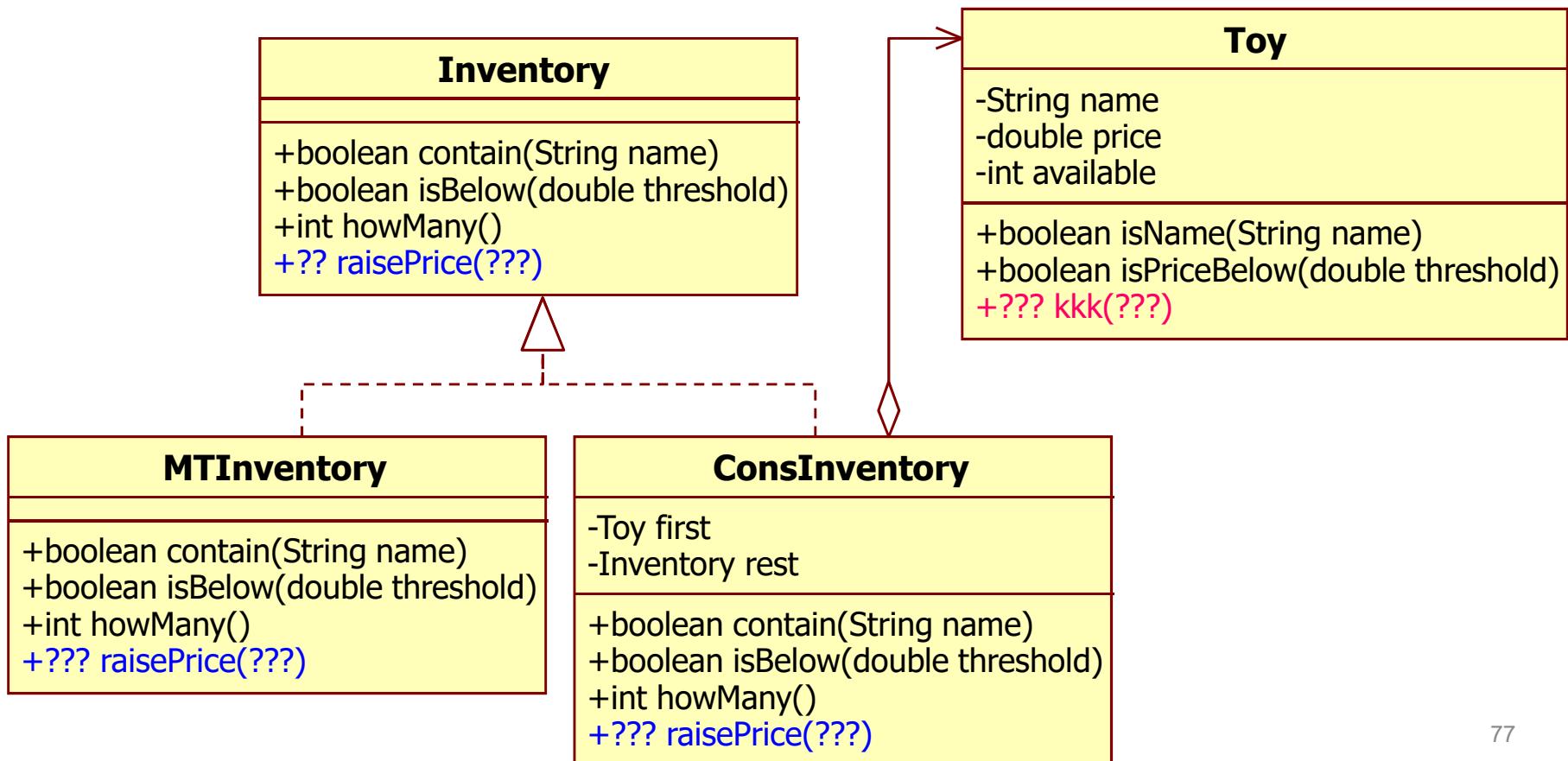
```
// inside of ConsInventory class
public int howMany() {
    return 1 + this.rest.howMany();
}
```

Test howMany()

```
public void testHowMany() {  
    Toy doll = new Toy("doll", 17.95, 5);  
    Toy robot = new Toy("robot", 22.05, 3);  
    Toy gun = new Toy ("gun", 15.0,4);  
  
    Inventory empty = new MTInventory();  
    Inventory i1 = new ConsInventory(doll, empty);  
    Inventory i2 = new ConsInventory(robot, i1);  
    Inventory all = new ConsInventory(doll,  
                                       new ConsInventory(robot,  
                                         new ConsInventory(gun, new MTInventory()))));  
  
    assertEquals(0, empty.howMany());  
    assertEquals(1, i1.howMany());  
    assertEquals(2, i2.howMany());  
    assertEquals(3, all.howMany());  
}
```

Add `raisePrice()` method

- Develop the method `raisePrice`, which produces an inventory in which all prices are raised by a given rate



Purpose and contract of `raisePrice()` for `Inventory` - Immutable version

- **Q:** what does the `raisePrice()` method return?
- **A:** It returns a new `Inventory` whose each element has new price

```
public interface Inventory {  
    ...  
    // raise all prices of toys  
    // in the Inventory with rate  
    public Inventory raisePrice(double rate);  
}
```

Examples to test `raisePrice()`

```
Toy doll = new Toy("doll", 17.95, 5);
Toy robot = new Toy("robot", 22.05, 3);
Toy gun = new Toy ("gun", 15.0, 4);

Inventory empty = new MTInventory();
Inventory all = new ConsInventory(doll,
                                   new ConsInventory(robot,
                                   new ConsInventory(gun, new MTInventory())));

empty.raisePrice(0.05) → should be new MTLog()
all.raisePrice(0.05) → new ConsLog(new Toy("doll", 18.8475, 5),
                                   new ConsLog(new Toy("robot", 23.1525, 5),
                                   new ConsLog(new Toy("gun", 15.75, 5),
                                   new MTLog()))))
```

raisePrice() for MTInventory and ConsInventory

```
// inside of MTInventory class
public Inventory raisePrice(double rate) {
    return new MTInventory();
}
```

```
// inside of ConsInventory class
public Inventory raisePrice(double rate) {
    Toy aToy = this.first.copyWithRaisePrice(rate);
    return new ConsInventory(aToy, this.rest.raisePrice(rate));
}
```

```
// inside of Toy class
public Toy copyWithRaisePrice(double rate) {
    return new Toy(this.name,
                  this.price * (1 + rate), this.available);
}
```

Test `raisePrice()`

```
public void testRaisePrice(){
    Toy doll = new Toy("doll", 17.95, 5);
    Toy robot = new Toy("robot", 22.05, 3);
    Toy gun = new Toy ("gun", 15.0,4);

    Inventory all = new ConsInventory(doll,
        new ConsInventory(robot,
            new ConsInventory(gun, new MTInventory())));

    assertEquals(all.raisePrice(0.05),
        new ConsLog(new Toy("doll", 18.8475, 5),
            new ConsLog(new Toy("robot", 23.1525, 5),
                new ConsLog(new Toy("gun", 15.75, 5),
                    new MTLog()))));
    System.out.println(all.raisePrice(0.05));
}
```

equals() method

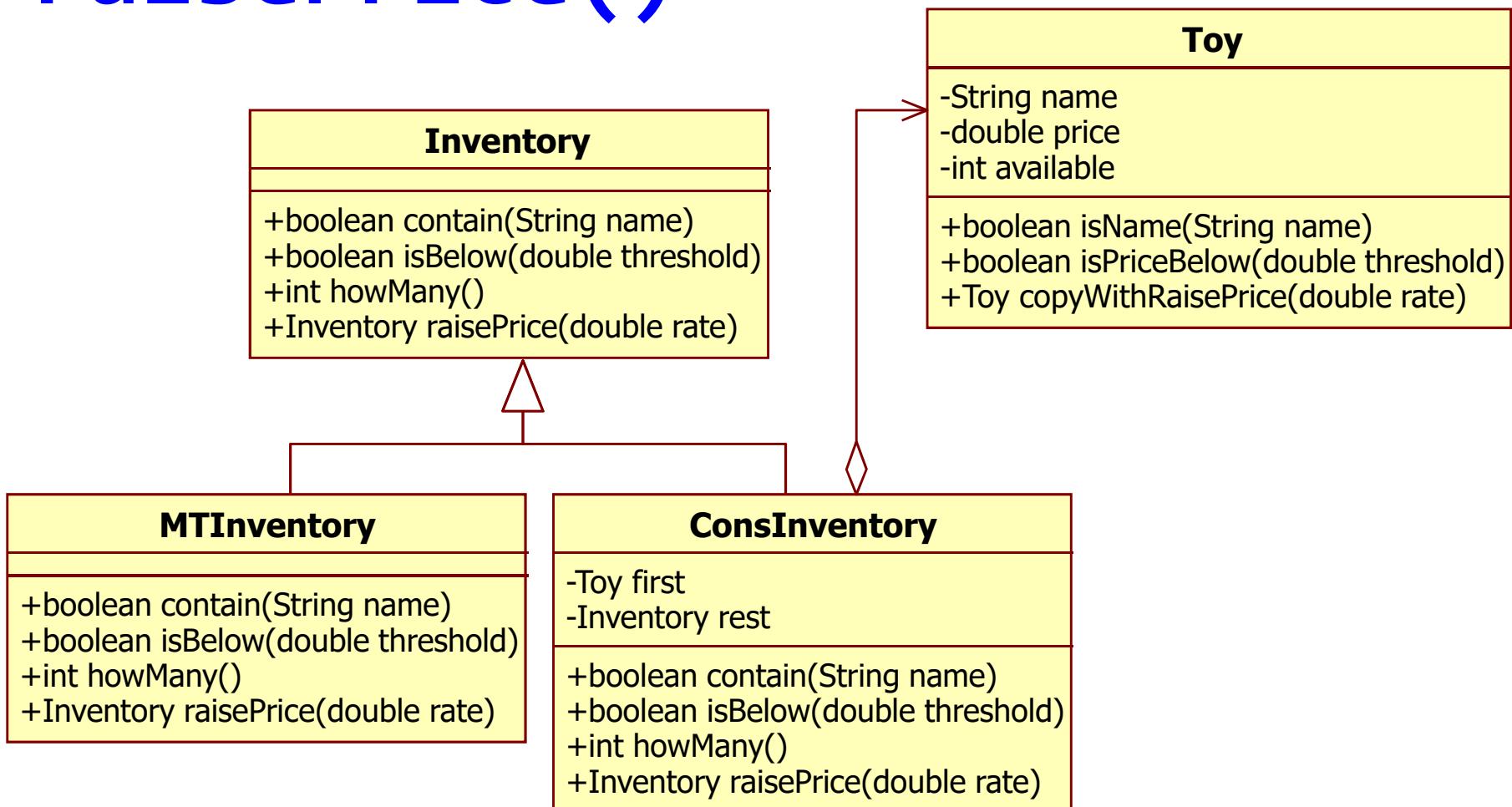
```
// in MTInventory class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof MTInventory))
        return false;
    return true;
}
```

```
// inside ConsInventory class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof ConsInventory))
        return false;
    else {
        ConsInventory that = (ConsInventory) obj;
        return this.first.equals(that.first)
            && this.rest.equals(that.rest);
    }
}
```

equals() method in Toy

```
// in Toy class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof Toy))
        return false;
    else {
        Toy that = (Toy) obj;
        return this.name.equals(that.name) &&
               this.price == that.price &&
               this.available == that.available;
    }
}
```

Class diagram after add raisePrice()



Purpose and contract of `raisePrice()` for `Inventory` - mutable version

- **Q:** what does the `raisePrice()` method return?
- **A:** It just updates `Inventory` whose each element has new price and return `void`.

```
public interface Inventory {  
    // raise all prices of toys  
    // in the Inventory with rate  
    public void raisePriceMutable(double rate);  
}
```

raisePrice() for MTInventory and ConsInventory

```
// inside of MTInventory class
public void raisePriceMutable(double rate) { }
```

```
// inside of ConsInventory class
public void raisePriceMutable(double rate) {
    this.first.setNewPrice(rate); ←
    this.rest.raisePriceMutable(rate);
}
```

Delegation to
Toy object

setNewPrice() in Toy class

```
public void setNewPrice(double rate) {
    this.price = this.price * (1 + rate);
}
```

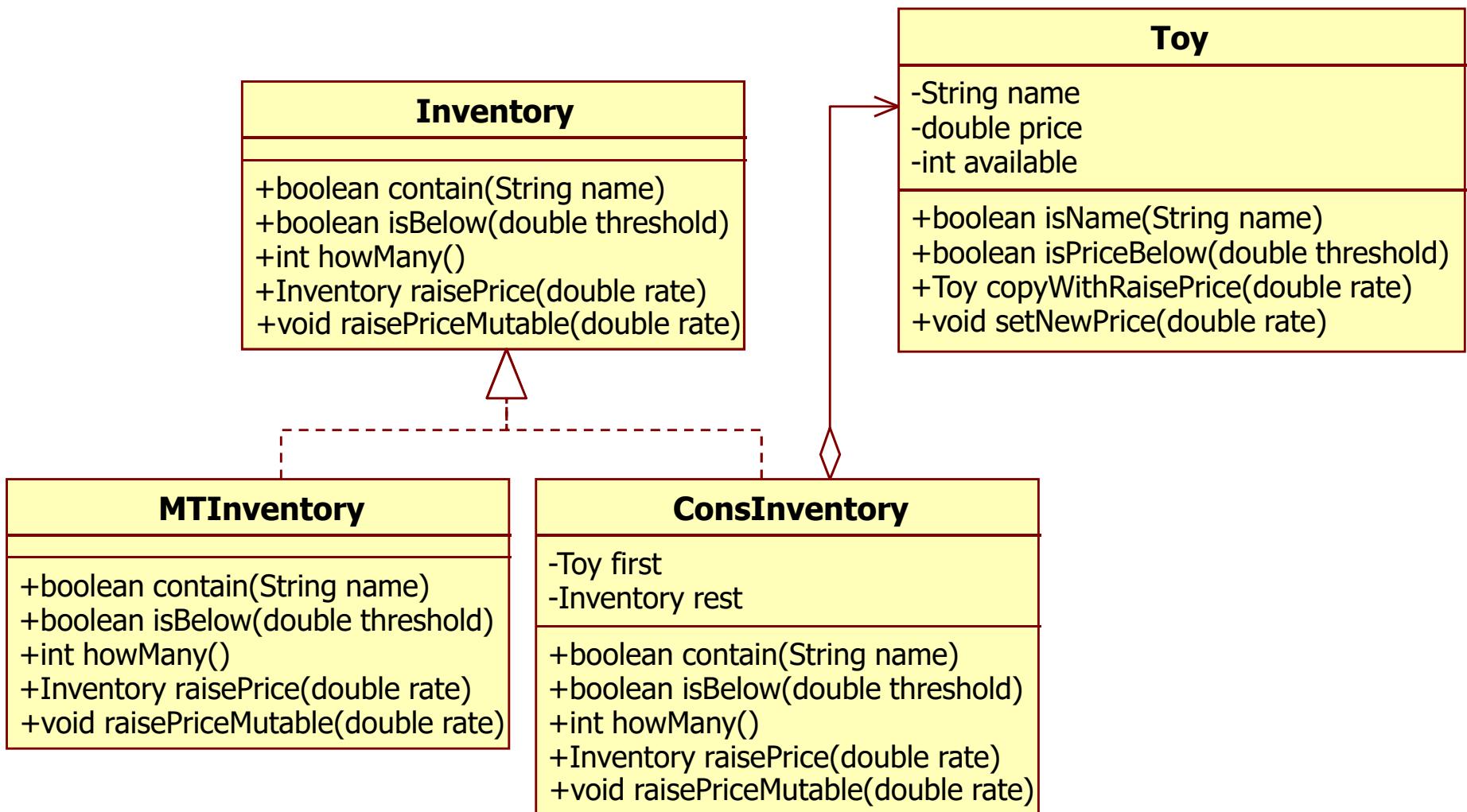
Test `raisePriceMutable()`

```
public void testRaisePrice(){
    Toy doll = new Toy("doll", 17.95, 5);
    Toy robot = new Toy("robot", 22.05, 3);
    Toy gun = new Toy ("gun", 15.0,4);

    Inventory all = new ConsInventory(doll,
        new ConsInventory(robot,
            new ConsInventory(gun, new MTInventory())));

    all.raisePriceMutable(0.05);
    // after invoking raisePriceMutable(rate)
    assertEquals(all,
        new ConsLog(new Toy("doll", 18.8475, 5),
            new ConsLog(new Toy("robot", 23.1525, 5),
                new ConsLog(new Toy("gun", 15.75, 5),
                    new MTLog()))));
    );
    System.out.println(all);
}
```

Final class diagram

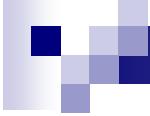


Exercise 6.1

6.1.1 Define the method **averagePrice**. It computes the average price of toys in **Inventory**. The average is the total of all prices divided by the number of toys

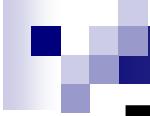
6.1.2 Develop the method **replaceName**, which consumes a list of toy and replaces all occurrences of “**robot**” with “**r2d2**” and otherwise retains the toy descriptions in the same order.

6.1.3 Develop the method **eliminate**. The method consumes a string, called **toyOfName** and produces a list of toys that contains all components of list with the exception of the toy whose name matches **toyOfName**.



Exercise 6.2

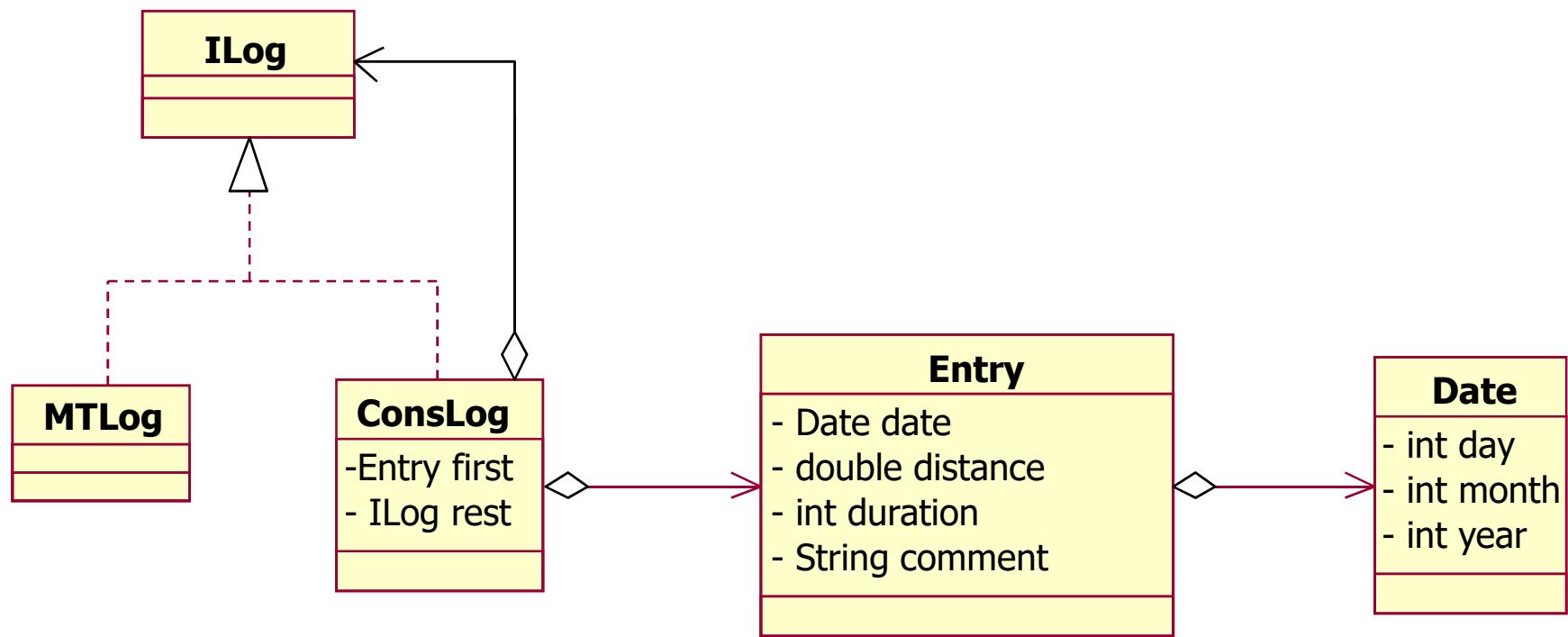
- A phone directory combines names with phone numbers. Develop a data definition for phone records and directories.
Develop the methods:
 - **whoseNumber**, which determines the name that goes with some given phone number and phone directory.
 - **phoneNumber**, which determines the phone number that goes with some given name and phone directory



Recall the problem of tracking a runner's workouts

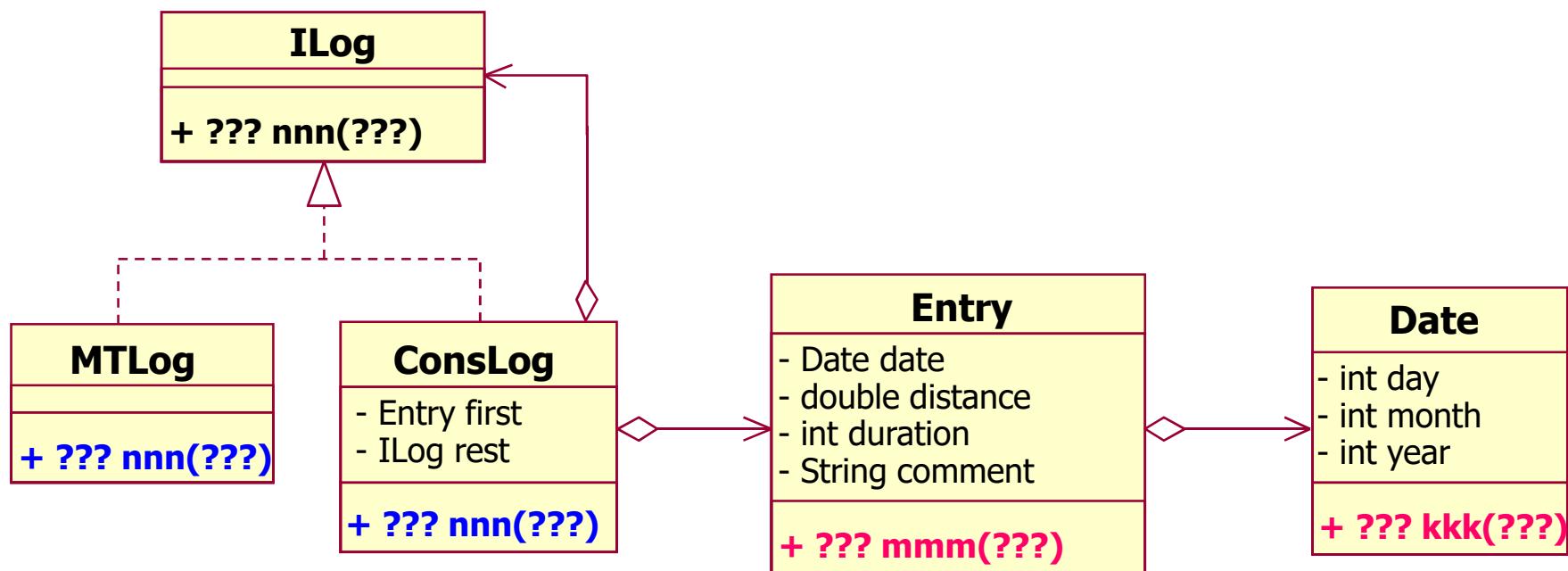
- Develop a program that manages a runner's training log. Every day the runner enters one entry concerning the day's run.
 - ...For each entry, the program should compute how fast the runner ran (Exercise 3.1.4 & 3.1.5 in week 1).
 - ...*The runner may also wish to determine the total number of miles run*

Class diagram for a runner's log



Add methods to the runner's log

Class Diagram



Q: Write Java method templates for all the classes in the class diagram ?

Java template for ILog and MTLog

```
public interface ILog {  
    public ??? nnn(???);  
}
```

```
public class MTLog implements ILog {  
  
    public ??? nnn(???) {  
        ...  
    }  
}
```

Java template for ConsLog

```
public class ConsLog implements ILog {  
    private Entry first;  
    private ILog rest;  
  
    public ConsLog(Entry first, ILog rest) {  
        this.first = first;  
        this.rest = rest;  
    }  
  
    public ??? nnn(???) {  
        ... this.first.mmm(??) ...  
        ... this.rest.nnn(??) ...  
    }  
}
```

Java template for Entry

```
public class Entry {  
    private Date date;  
    private double distance;  
    private int duration;  
    private String comment;  
    public Entry(Date date, double distance,  
                int duration, String comment) {  
        this.date = date;  
        this.distance = distance;  
        this.duration = duration;  
        this.comment = comment;  
    }  
    public ??? mmm(???) {  
        ... this.date.kkk(??) ...  
        ... this.distance ...  
        ... this.duration ...  
        ... this.comment ...  
    }  
}
```

Java template for Date

```
public class Date {  
    private int day;  
    private int month;  
    private int year;  
  
    public Date(int day, int month, int year) {  
        this.day = day;  
        this.month = month;  
        this.year = year;  
    }  
  
    public ??? kkk(???) {  
        ... this.day ...  
        ... this.month ...  
        ... this.year ...  
    }  
}
```

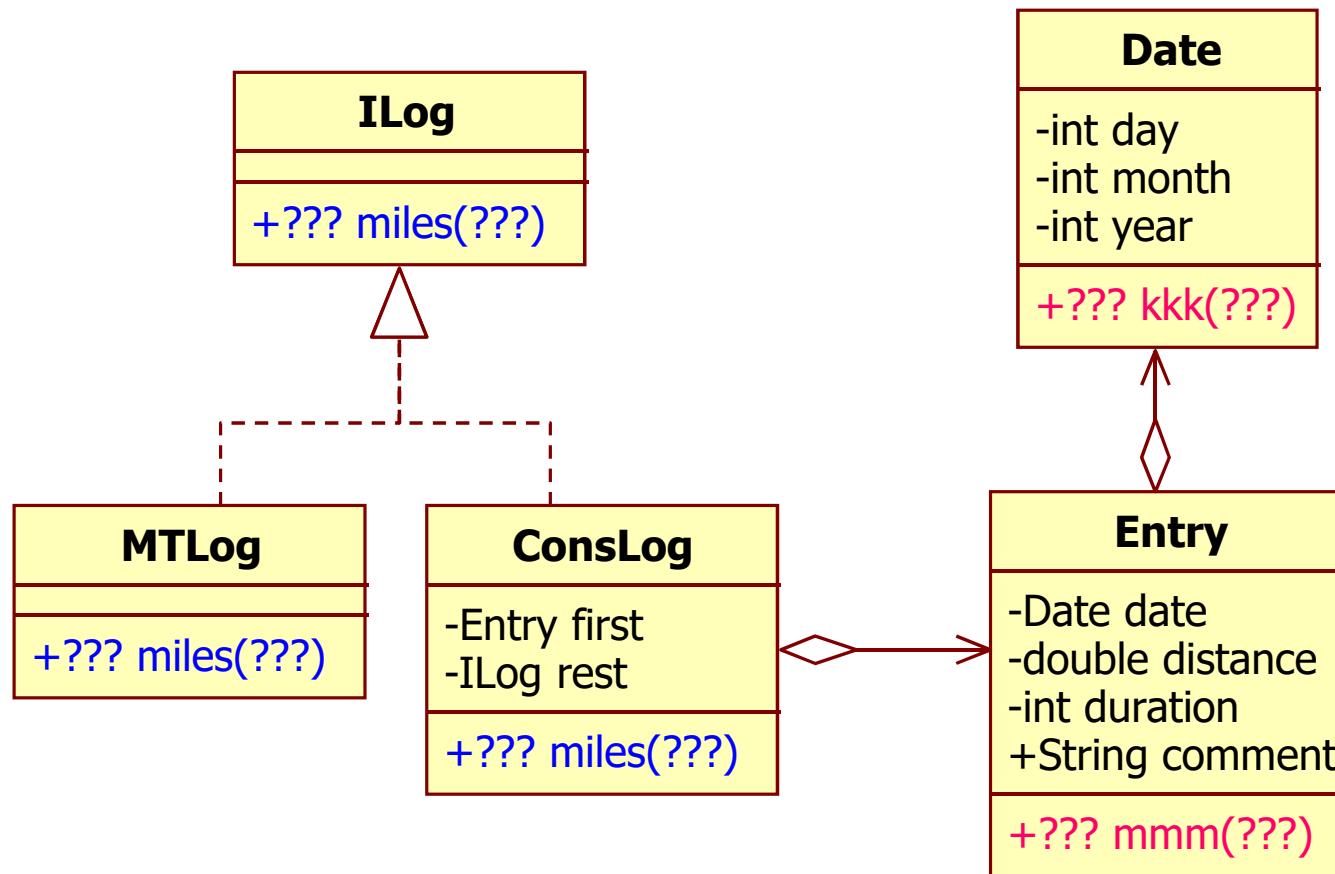
Examples for a runner's log

```
Entry e1 = new Entry(new Date(5, 5, 2005), 5.0, 25, "Good");
Entry e2 = new Entry(new Date(6, 6, 2005), 3.0, 24, "Tired");
Entry e3 = new Entry(new Date(23, 6, 2005), 26.0, 156, "Great");

ILog log = new ConsLog(e1, new ConsLog(e2,
    new ConsLog(e3, new MTLog())));
```

Compute the total number of miles run

- Using the method template for ILog, design a method to **compute the total number of miles run**



miles() for ILog

```
public interface ILog {  
    // to compute the total number of miles  
    // recorded in this log  
    public double miles();  
}
```

Q: Develop some examples to test the `miles()` method

Examples to test miles()

```
Entry e1 = new Entry(new Date(5, 5, 2005), 5.0, 25, "Good");
Entry e2 = new Entry(new Date(6, 6, 2005), 3.0, 24, "Tired");
Entry e3 = new Entry(new Date(23, 6, 2005), 26.0, 156, "Great");

ILog 10 = new MTLog();
ILog 11 = new ConsLog(e1, 10);
ILog 12 = new ConsLog(e2, 11);
ILog 13 = new ConsLog(e3, 12);

10.miles() → should be 0.0
11.miles() → should be 5.0
12.miles() → should be 8.0
13.miles() → should be 34.0
```

Q: Implement miles() in MTLog and ConsLog

Implement miles()

in MTLog

```
public class MTLog implements ILog {  
    ...  
    public double miles() {  
        return 0.0;  
    }  
}
```

in ConsLog

```
public class ConsLog implements ILog {  
    ...  
    public double miles() {  
        return this.first.getDistance() +  
            this.rest.miles();  
    }  
}
```

getDistance() in Entry

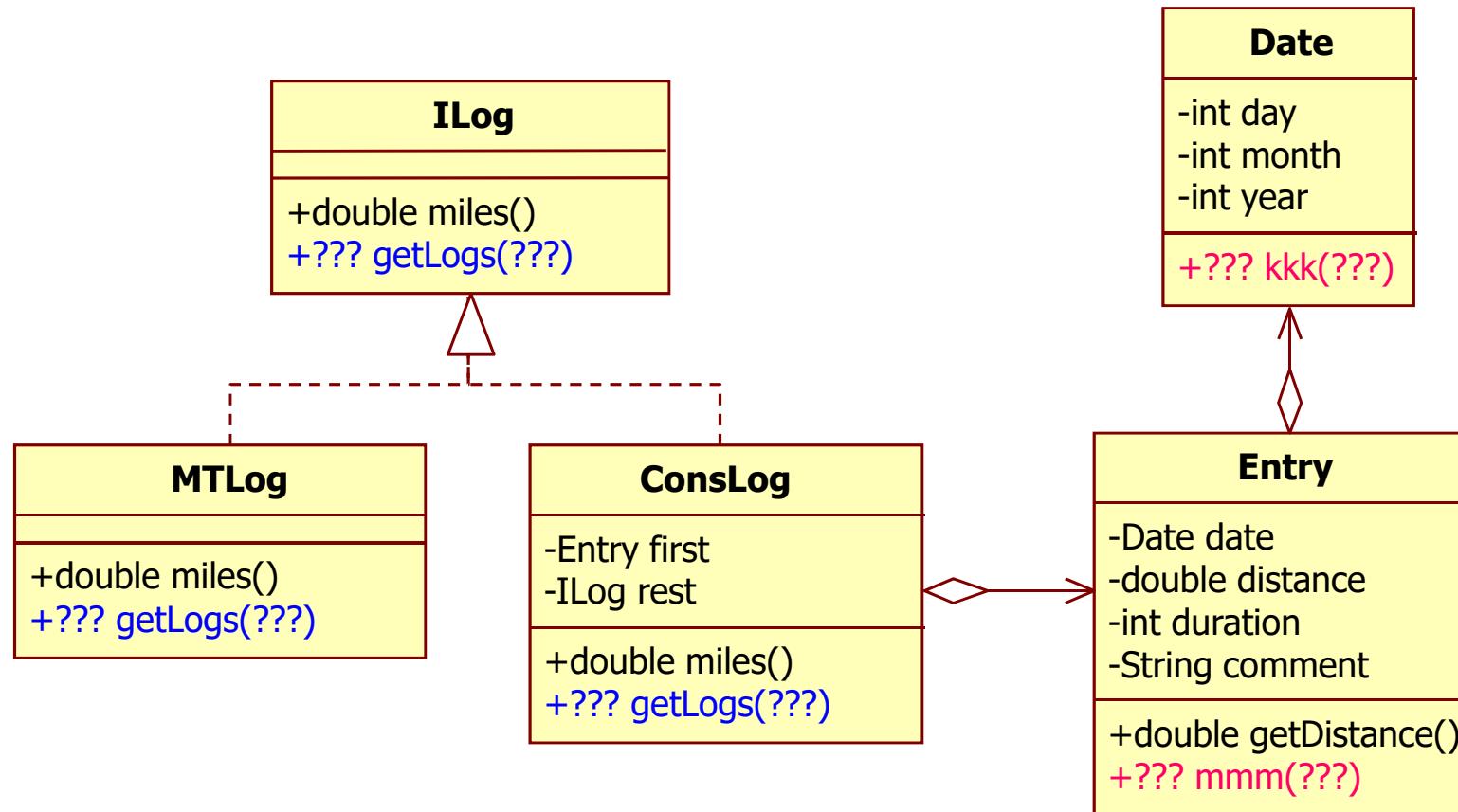
```
public class Entry {  
    private Date date;  
    private double distance;  
    private int duration;  
    private String comment;  
  
    ...  
    public double getDistance() {  
        return this.distance;  
    }  
}
```

Test miles() method

```
public void testMiles() {  
    Entry e1 = new Entry(new Date(5, 5, 2005), 5.0, 25, "Good");  
    Entry e2 = new Entry(new Date(6, 6, 2005), 3.0, 24, "Tired");  
    Entry e3 = new Entry(new Date(23, 6, 2005), 26.0, 156, "Great");  
  
    ILog l0 = new MTLog();  
    ILog l1 = new ConsLog(e1, l0);  
    ILog l2 = new ConsLog(e2, l1);  
    ILog l3 = new ConsLog(e3, l2);  
  
    assertEquals(l0.miles(), 0.0);  
    assertEquals(l1.miles(), 5.0);  
    assertEquals(l2.miles(), 8.0);  
    assertEquals(l3.miles(), 34.0);  
}
```

Extension of the runner's log problem

... The runner wants to see his log for a specific month of his training season. ...



getLogs() for ILog

```
public interface ILog {  
    // to compute the total number of miles  
    // recorded in this log  
    public double miles();  
  
    // to extract those entries in this log  
    // for the given month and year  
    public ILog getLogs(int month, int year);  
}
```

Q: Develop some examples to test the `getLogs()` method

Examples to test getLogs()

```
Entry e1 = new Entry(new Date(5, 5, 2005), 5.0, 25, "Good");
Entry e2 = new Entry(new Date(6, 6, 2005), 3.0, 24, "Tired");
Entry e3 = new Entry(new Date(23, 6, 2005), 26.0, 156, "Great");

ILog l0 = new MTLog();
ILog l1 = new ConsLog(e1, l0);
ILog l2 = new ConsLog(e2, l1);
ILog l3 = new ConsLog(e3, l2);

l0.getLogs(6, 2005) → should be new MTLog()
l1.getLogs(6, 2005) → should be new MTLog()
l2.getLogs(6, 2005) → should be new ConsLog(e2, new MTLog())
l3.getLogs(6, 2005) → should be
    new ConsLog(e3, new ConsLog(e2, new MTLog()))
```

Q: Implement getLogs() in MTLog and ConsLog

getLog() for MTLog

```
public class MTLog implements ILog {  
    // ...  
  
    public ILog getLogs(int month, int year) {  
        return new MTLog();  
    }  
}
```

getLogs() for ConsLog

```
public class ConsLog implements ILog {  
    private Entry first;  
    private ILog rest;  
    // ...  
  
    public ILog getLogs(int month, int year) {  
        if (this.first.sameMonthInAYear(month, year))  
            return new ConsLog(this.first,  
                               this.rest.getLogs(month, year));  
        else  
            return this.rest.getLogs(month, year);  
    }  
}
```

sameMonthInAYear() in Entry

```
public class Entry {  
    private Date date;  
    private double distance;  
    private int duration;  
    private String comment;  
    //...  
    public double getDistance() {  
        return this.distance;  
    }  
  
    // was this entry made in the given month and year  
    public boolean sameMonthInAYear(int month, int year) {  
        return this.date.sameMonthInAYear(month, year);  
    }  
}
```

sameMonthInAYear() in Date

```
public class Date {  
    private int day;  
    private int month;  
    private int year;  
  
    public Date(int day, int month, int year) {  
        this.day = day;  
        this.month = month;  
        this.year = year;  
    }  
  
    public boolean sameMonthInAYear(int month, int year) {  
        return (this.month == month) &&  
               (this.year == year);  
    }  
}
```

Q: Review delegation ?

Test getLogs()

```
public void testGetLogs() {  
    Entry e1 = new Entry(new Date(5, 5, 2005), 5.0, 25, "Good");  
    Entry e2 = new Entry(new Date(6, 6, 2005), 3.0, 24, "Tired");  
    Entry e3 = new Entry(new Date(23, 6, 2005), 26.0, 156, "Great");  
  
    ILog l0 = new MTLog();  
    ILog l1 = new ConsLog(e1, l0);  
    ILog l2 = new ConsLog(e2, l1);  
    ILog l3 = new ConsLog(e3, l2);  
  
    assertEquals(l0.getLogs(6, 2005), new MTLog());  
    assertEquals(l1.getLogs(6, 2005), new MTLog());  
    assertEquals(l2.getLogs(6, 2005),  
                new ConsLog(e2, new MTLog()));  
    assertEquals(l3.getLogs(6, 2005),  
                new ConsLog(e3, new ConsLog(e2, new MTLog())));  
}
```

equals() method

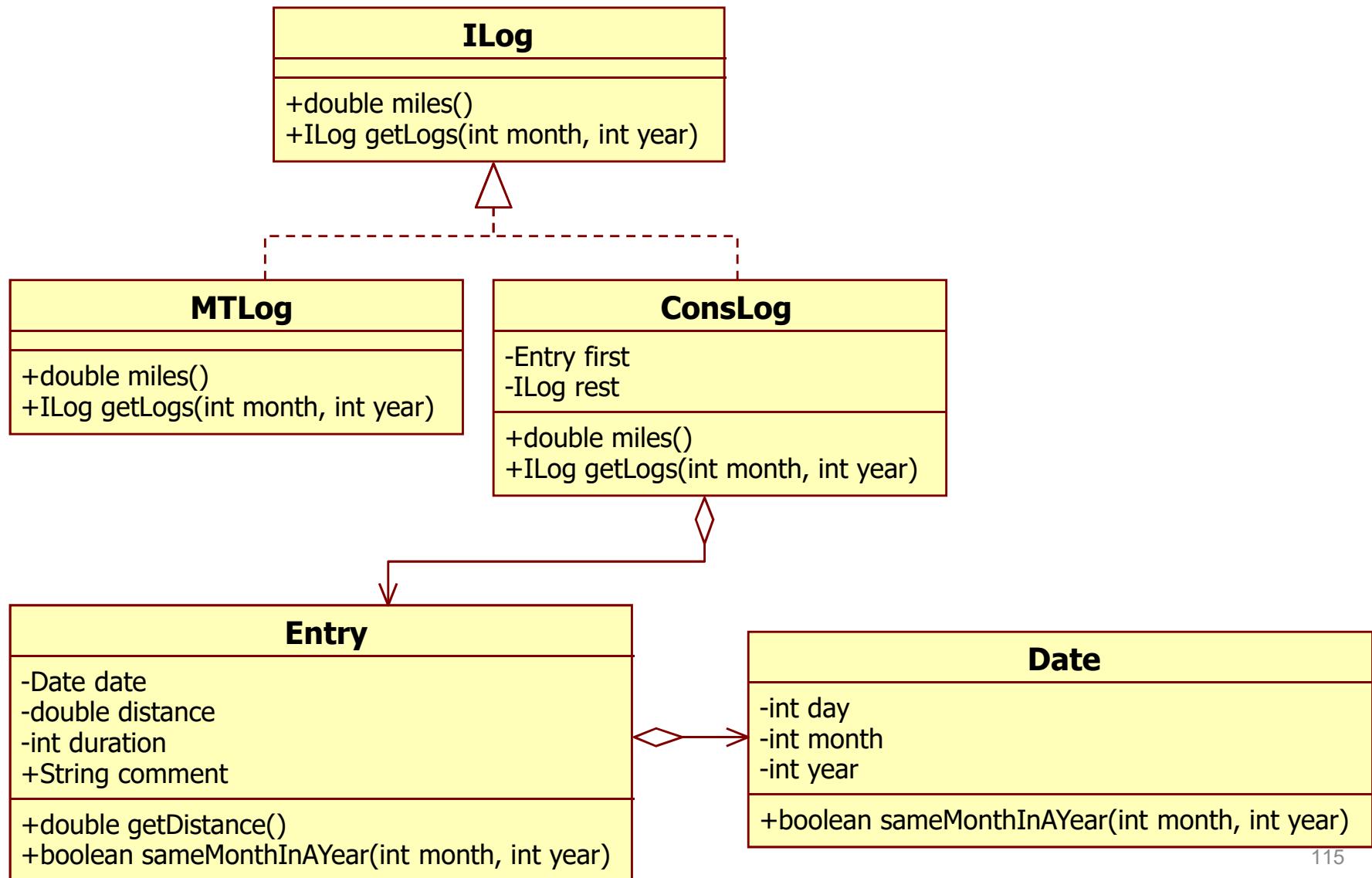
```
// in MTLog class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof MTLog))
        return false;
    return true;
}
```

```
// inside ConsLog class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof ConsLog))
        return false;
    else {
        ConsLog that = (ConsLog) obj;
        return this.first.equals(that.first)
            && this.rest.equals(that.rest);
    }
}
```

```
// in Entry class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof Entry))
        return false;
    else {
        Entry that = (Entry) obj;
        return this.date.equals(that.date) &&
               this.distance == that.distance &&
               this.durationInMinutes == that.durationInMinutes &&
               this.postRunFeeling.equals(that.postRunFeeling);
    }
}
```

```
// inside Date class
public boolean equals(Object obj) {
    if (obj == null || !(obj instanceof Date))
        return false;
    else {
        Date that = (Date) obj;
        return this.day == that.day &&
               this.month == that.month &&
               this.year == that.year;
    }
}
```

Class diagram



Exercise 6.3

Suppose the requirements for the program that tracks a runner's log includes this request:

1. The runner wants to know **the total distance run in a given month...**

Design the method that computes this number

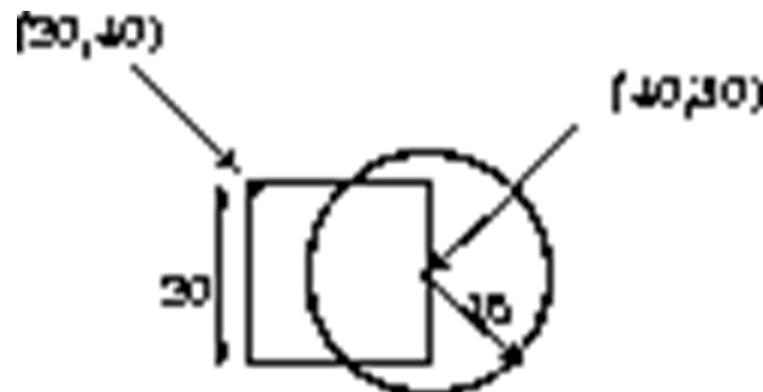
2. A runner wishes to know **the maximum distance ever run ...**

Design the method that computes this number.

Assume that the method produces 0 if the log is empty.

Exercise 6.4: Overlapping Shapes

- Develop a drawing program that deals with at least three kinds of shapes: dots, squares, and circles. ...In addition, the program should also deal with overlaying shapes on each other. In the following figure, for example, we have superimposed a circle on the right side of a square:



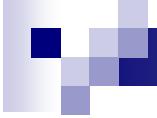
- We could now also superimpose this compounded shape on another shape and so on.

Problem1

1. The user wishes to know how close a combination of shapes is to the origin ...
2. Add a method that determines whether some point in the Cartesian space falls within the boundaries of some shape.
3. A graphics program must compute the bounding box for a shape.



List Sorting

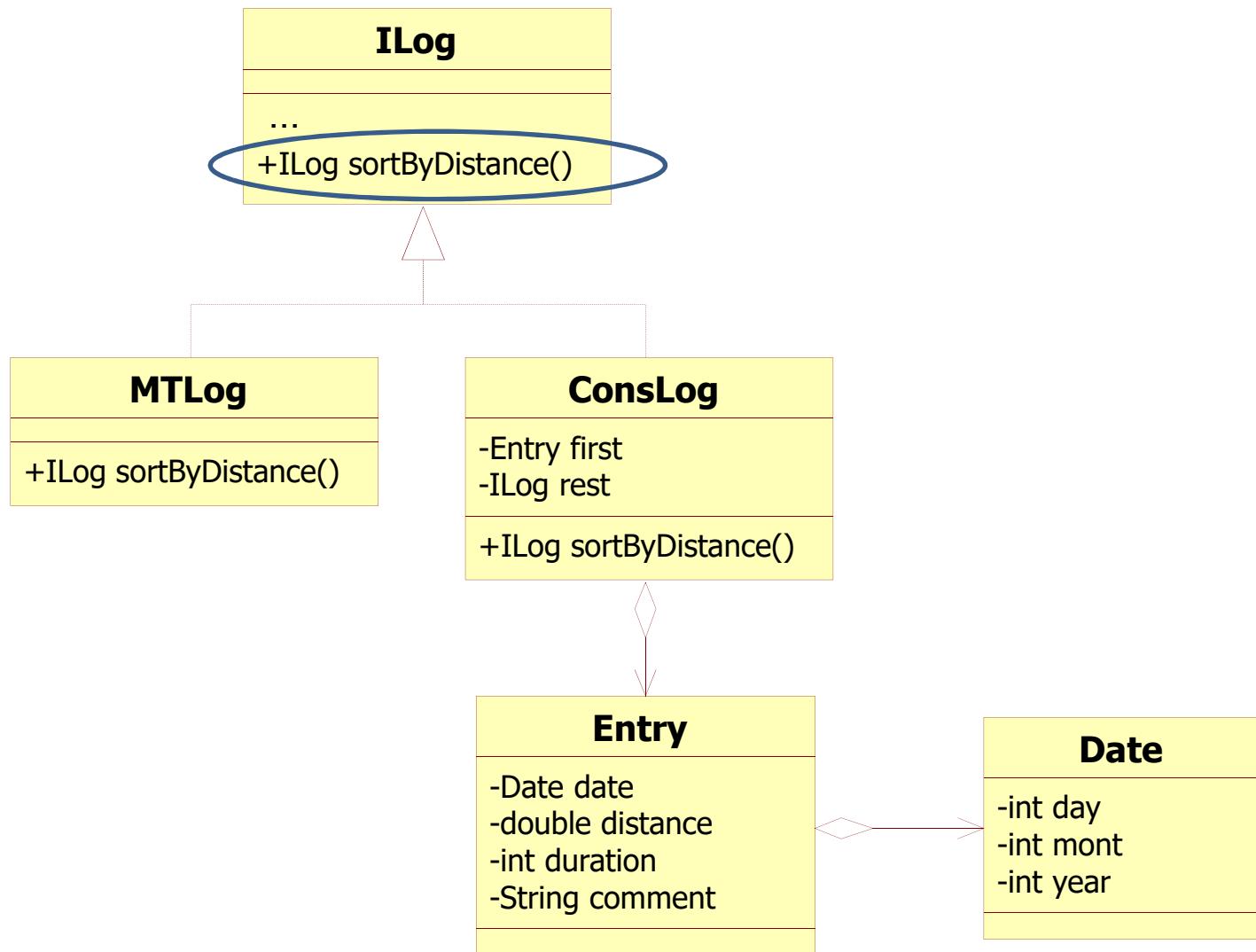


Problem Statement

The runner would like to **see the log** with entries ordered according to the distance covered in each run, from the shortest to the longest distance.

- **Q:** Which class should this operation belong to?

Modification of ILog



Examples

```
Entry e1 = new Entry(new Date(5, 5, 2005), 5.0, 25, "Good");
Entry e2 = new Entry(new Date(6, 6, 2005), 3.0, 24, "Tired");
Entry e3 = new Entry(new Date(23, 6, 2005), 26.0, 156, "Great");

ILog 10 = new MTLog();
ILog 11 = new ConsLog(e1, 10);
ILog 12 = new ConsLog(e2, 11);
ILog 13 = new ConsLog(e3, 12);

10.sortByDistance() → should be new MTLog()
11.sortByDistance() → should be new ConsLog(e1, new MTLog())

12.sortByDistance()
→ should be new ConsLog(e2, new ConsLog(e1, new MTLog())))

13.sortByDistance()
→ should be new ConsLog(e2, new ConsLog(e1,
                                         new ConsLog(e3, new MTLog())))

```

sortByDistance() in ILog

```
public interface ILog {  
    // ...  
  
    // to create from this log a new log with  
    // entries sorted by distance  
    public ILog sortByDistance();  
}
```

sortByDistance() in MTLog

```
public class MTLog implements ILog {  
    public MTLog() { }  
    // ...  
  
    public ILog sortByDistance() {  
        return new MTLog();  
    }  
}
```

Template of `sortByDistance()` in `ConsLog`

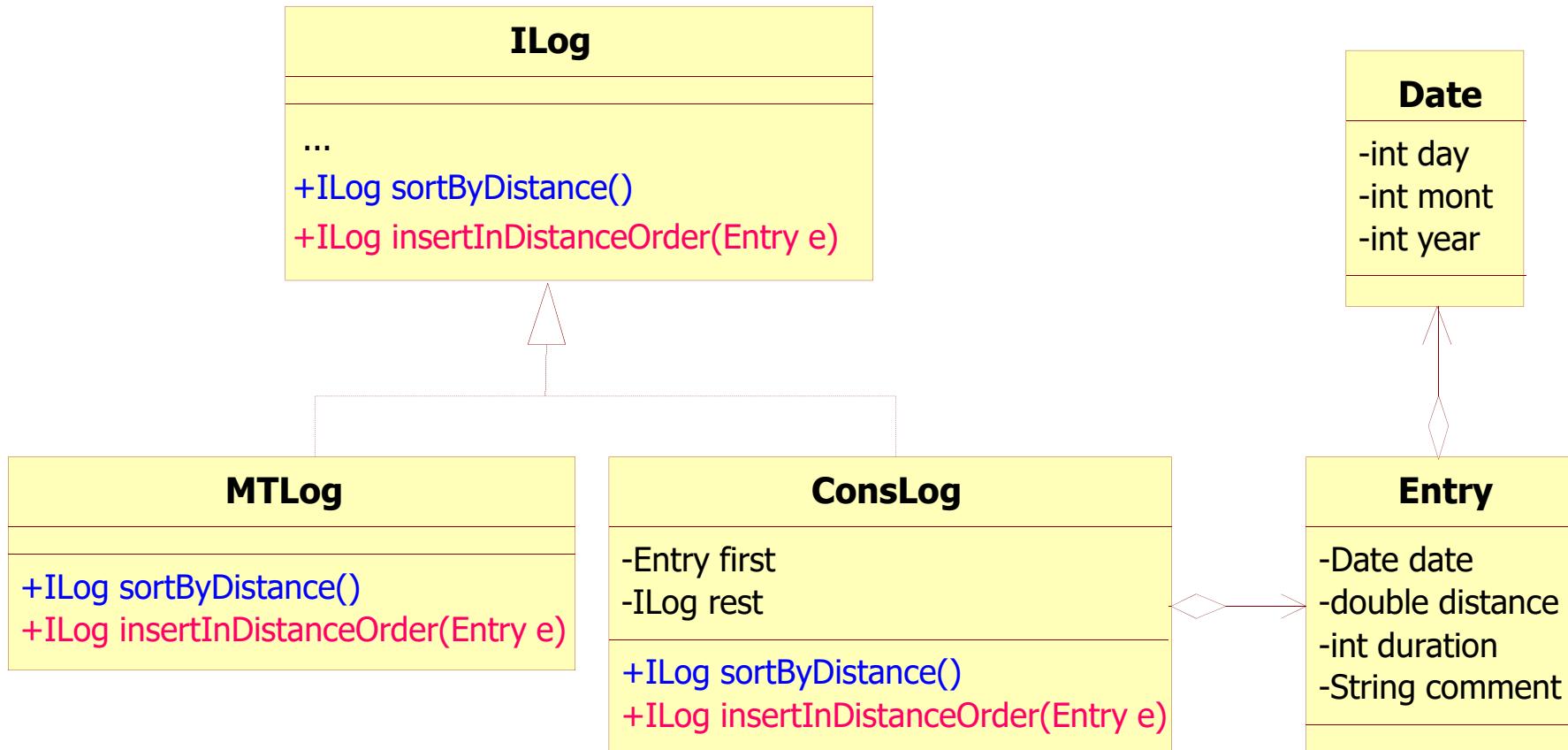
```
public class ConsLog implements ILog {  
    private Entry first;  
    private ILog rest;  
    // ...  
  
    public ILog sortByDistance() {  
        ... this.first.mmm(??) ...  
        ... this.rest.sortByDistance() ...  
    }  
}
```

Solution of `sortByDistance()` in `ConsLog`

- To sort a `ConsLog`, we need to insert the `first` entry into the **sorted version** of `rest` to obtain the whole sorted log.

```
public class ConsLog implements ILog {  
    private Entry first;  
    private ILog rest;  
    //...  
  
    public ILog sortByDistance() {  
        return this.rest.sortByDistance()  
            .insertInDistanceOrder(this.first);  
    }  
}
```

Modification of ILog



insertInDistanceOrder() in ILog

```
public interface ILog {  
    // ...  
    // to create from this log a new log with  
    // entries sorted by distance  
    public ILog sortByDistance();  
  
    // insert the given entry into  
    // this sorted log  
    public ILog insertInDistanceOrder(Entry e);  
}
```

Examples for `insertInDistanceOrder()`

```
Entry e1 = new Entry(new Date(5, 5, 2005), 5.0, 25, "Good");
Entry e2 = new Entry(new Date(6, 6, 2005), 3.0, 24, "Tired");
Entry e3 = new Entry(new Date(23, 6, 2005), 26.0, 156, "Great");
Entry e4 = new Entry(new Date(15, 7, 2005), 10.0, 61, "Tierd");

ILog l0 = new MTLog();
ILog l1 = l0.insertInDistanceOrder(e1);
// should be new new ConsLog(e1, new MTLog()))

ILog l2 = l1.insertInDistanceOrder(e2);
// should be new ConsLog(e2, new ConsLog(e1, new MTLog())))

ILog l3 = l2.insertInDistanceOrder(e3);
// should be new ConsLog(e2, new ConsLog(e1,
//           new ConsLog(e3, new MTLog())))

ILog l4 = l3.insertInDistanceOrder(e4);
// should be new ConsLog(e2, new ConsLog(e1, new ConsLog(e4,
//           new ConsLog(e3, new MTLog()))))
```

insertInDistanceOrder() in MTLog

```
public class MTLog implements ILog {  
    public MTLog() { }  
    // ...  
  
    public ILog sortByDistance() {  
        return new MTLog();  
    }  
  
    public ILog insertInDistanceOrder(Entry e) {  
        return new ConsLog(e, new MTLog());  
    }  
}
```

insertInDistanceOrder() in ConsLog

```
public class ConsLog implements ILog {  
    private Entry first;  
    private ILog rest;  
  
    public ILog sortByDistance() {  
        return this.rest.sortByDistance()  
            .insertInDistanceOrder(this.first);  
    }  
  
    public ILog insertInDistanceOrder(Entry e) {  
        if (e.hasDistanceShorterThan(this.first))  
            return new ConsLog(e, this);  
        else  
            return new ConsLog(this.first,  
                this.rest.insertInDistanceOrder(e));  
    }  
}
```

hasDistanceShorterThan() in Entry

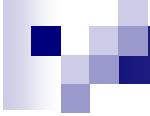
```
public class Entry {  
    private Date date;  
    private double distance;  
    private int duration;  
    private String comment;  
    // ...  
  
    public boolean hasDistanceShorterThan(Entry that) {  
        return this.distance <= that.distance;  
    }  
}
```

Test sortByDistance()

```
public void testSortByDistance() {  
    Entry e1 = new Entry(new Date(5, 5, 2005), 5.0, 25, "Good");  
    Entry e2 = new Entry(new Date(6, 6, 2005), 3.0, 24, "Tired");  
    Entry e3 = new Entry(new Date(23, 6, 2005), 26.0, 156, "Great");  
  
    ILog l0 = new MTLog();  
    ILog l1 = new ConsLog(e1, l0);  
    ILog l2 = new ConsLog(e2, l1);  
    ILog l3 = new ConsLog(e3, l2);  
  
    assertEquals(l0.sortByDistance(), new MTLog());  
    assertEquals(l1.sortByDistance(), new ConsLog(e1, MTLog()));  
    assertEquals(l2.sortByDistance(),  
                new ConsLog(e2, new ConsLog(e1, new MTLog())));  
    assertEquals(l3.sortByDistance(), new ConsLog(e2,  
                new ConsLog(e1, new ConsLog(e3, new MTLog()))));  
}
```



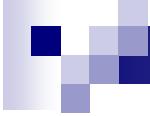
Exercises



Exercise 6.5

Suppose the requirements for the program that tracks a runner's log includes this request:

- ... The runner would like to see the log with entries ordered according to the pace computed in minutes per mile in each run, **from the fastest to the slowest**
...
- Design this sorting method.
Hint: Don't forget to design methods for auxiliary tasks.



Exercise 6.6

Develop a program that sorts lists of mail messages by date.

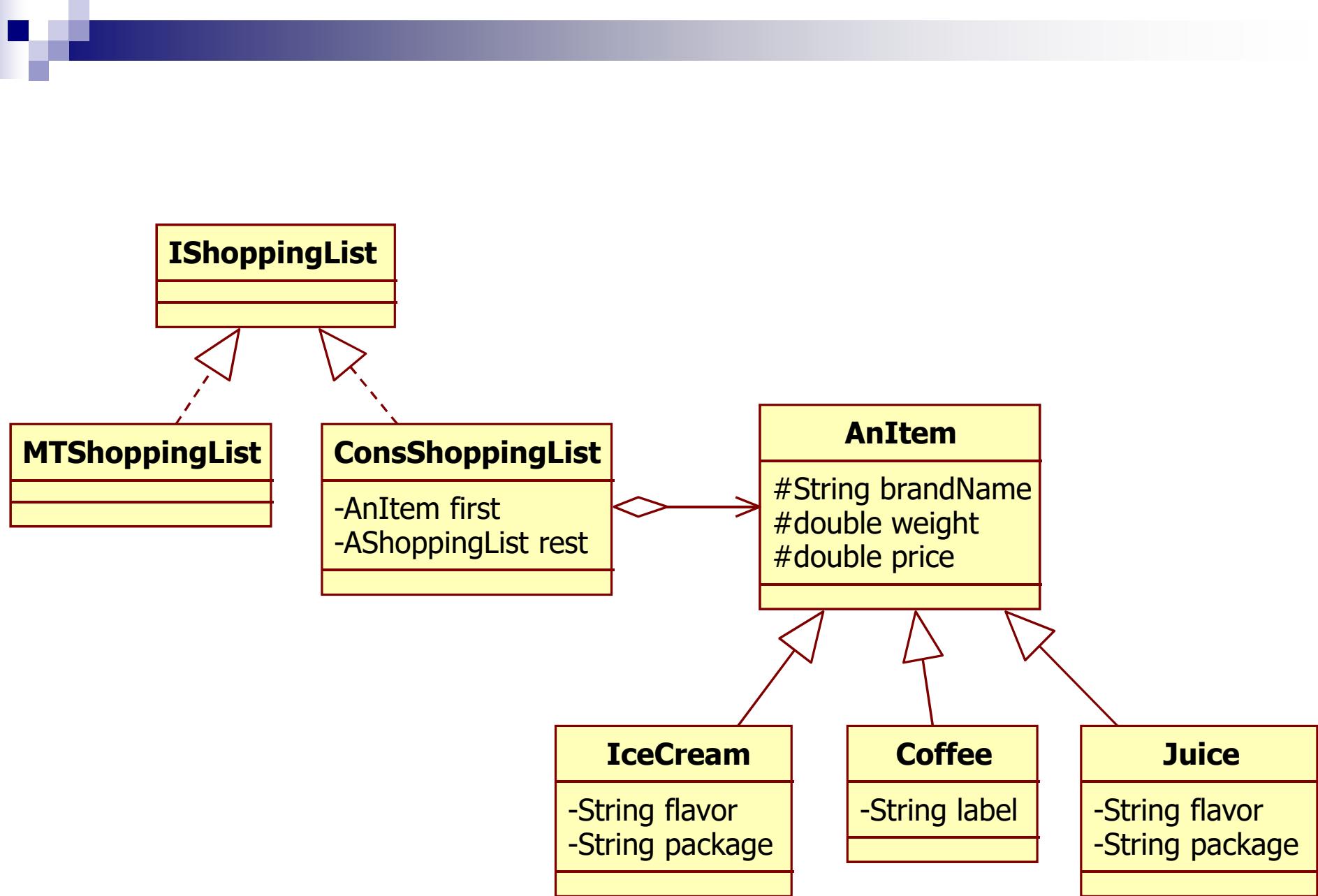
Mail structures are defined as follows: from, date, message

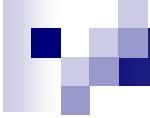
Exercise 6.7

Design a data representation for shopping lists.

Start from the class of grocery items developed in exercise 4.6. Add the following methods:

- `howMany`, which computes the number of items on the shopping list;
- `brandList`, which produces the list of all brand names;
- `highestPrice`, which determines the highest unit price among all items in the shopping list.



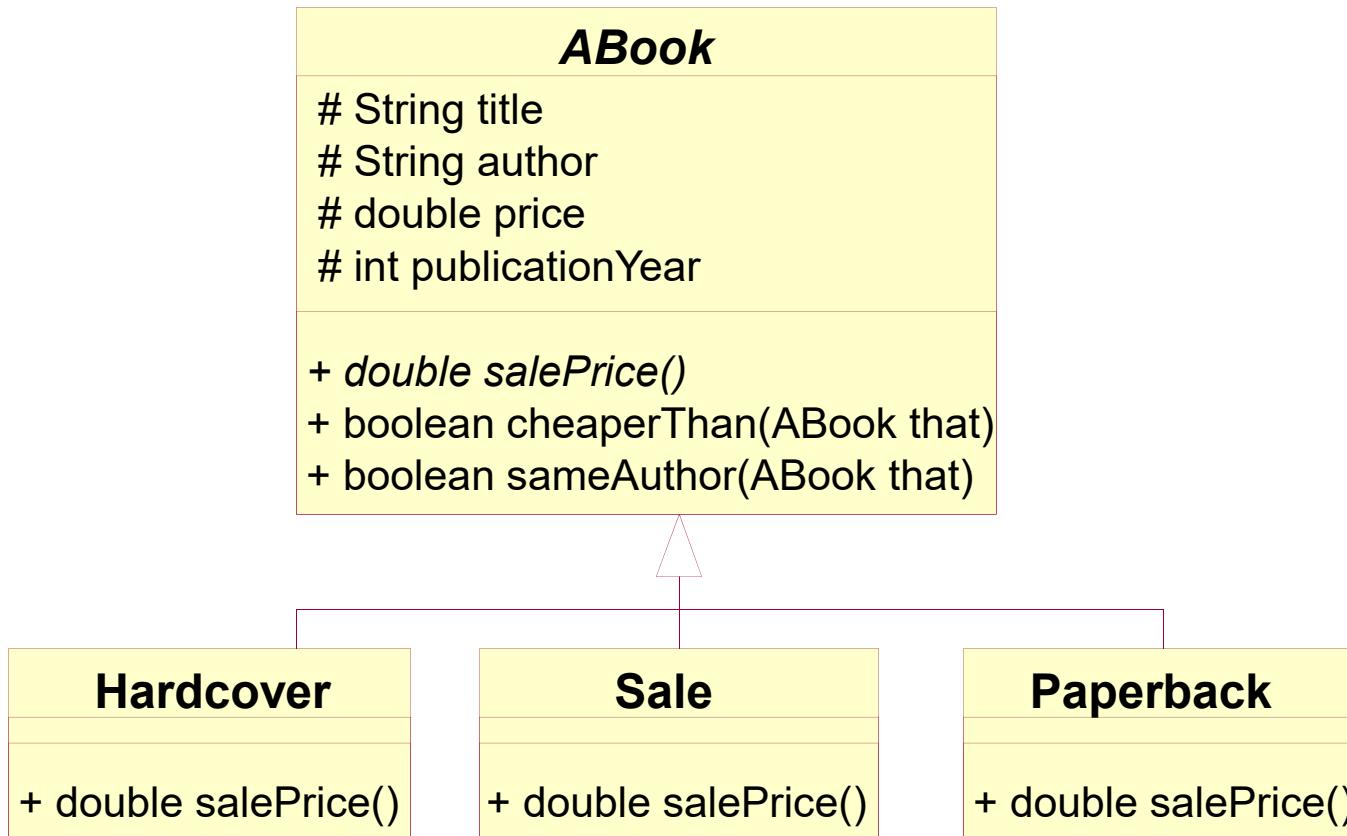


Exercise 6.8

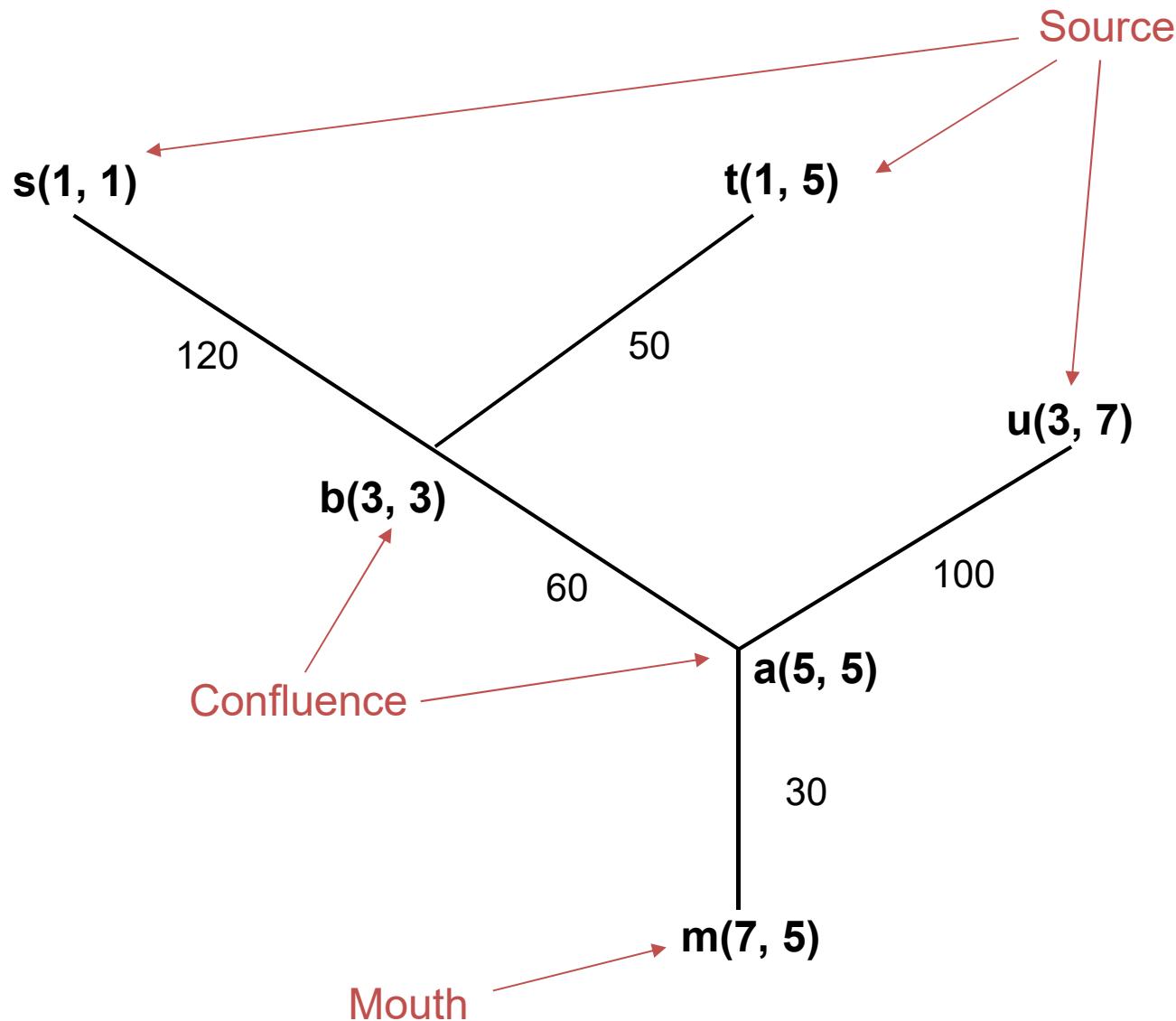
Develop a program for managing discount bookstores
(see exercise 4.8):

- Design a representation for lists of books;
- Write down (in English) three examples of book lists and their corresponding data representations;
- Develop the method `thisAuthor`, which produces the list of books that this author has authored.
- Develop the method `sortByTitle`, which sorts lists of books by title

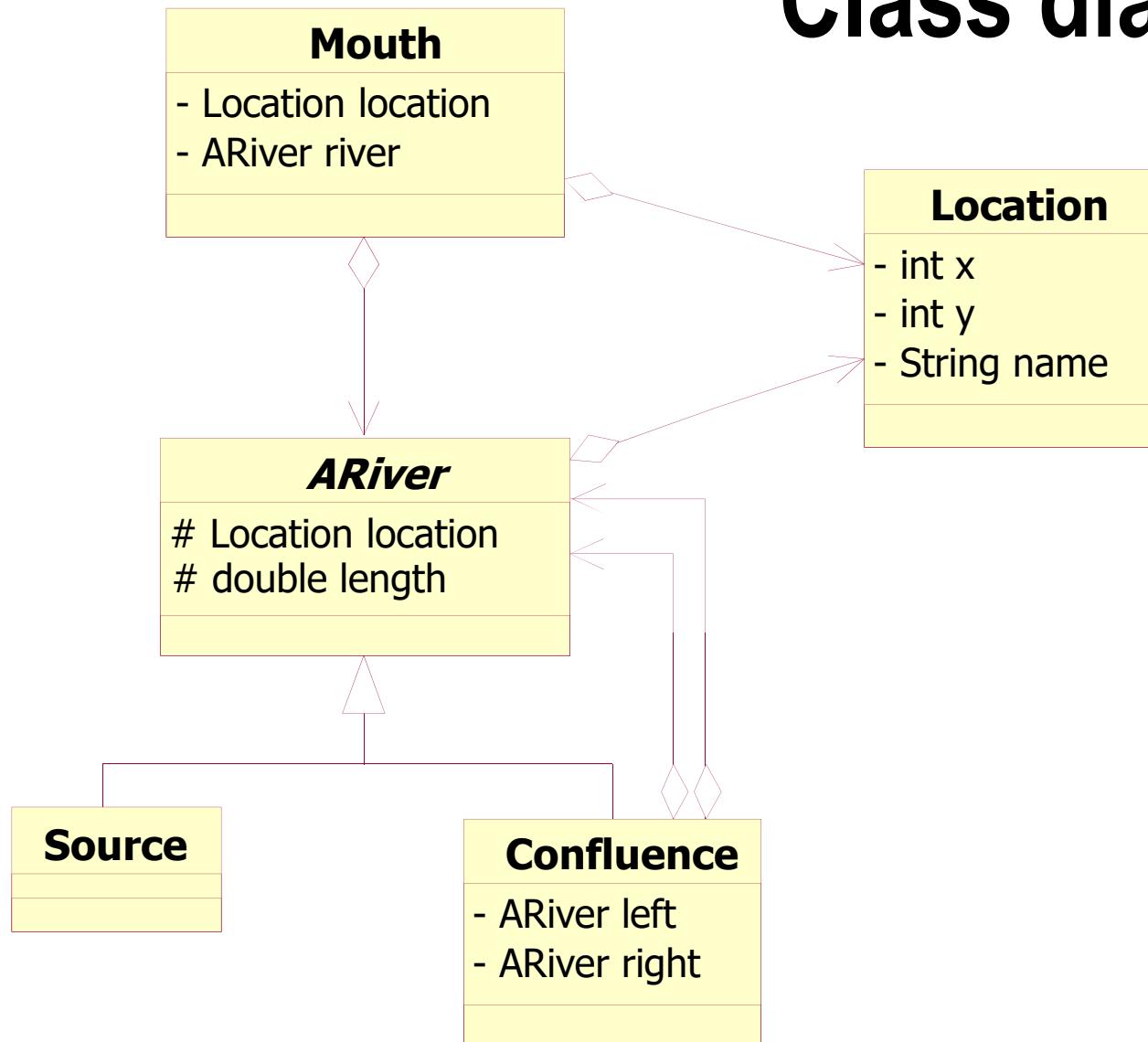
Exercise 6.6 Class Diagram

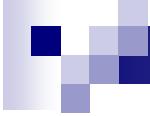


Exercise 6.9: River Systems



Class diagram





Problems

- The EPA must represent river systems and monitor them... An EPA officer may wish to query a computer about **the number of sources** that feed a river system.
- An EPA officer may wish to find out whether **some location is a part of a river system**, regardless of whether it is a source, a confluence, or the river mouth
- An EPA officer may request **the number of miles of a river system**, either starting from the river's mouth or any of its confluence points.
- An EPA officer may wish to find out whether **some location is within a given radius of some confluence or source on a river system**.

Problems

Extend the following methods to classes that represent river systems with the following methods:

- **maxlength**, which computes the length of the longest river segment;
- **confluences**, which counts the number of confluences in the river system; and
- **locations**, which produces a list of all locations on this river -- the sources, the mouths, and the confluences.



Relax & ...Do Exercises ...

Too much hard exercises now

Try again, never stop practicing!