Unions of Classes and Methods

Introduction

- Our railroad example ***distinguishes between two kinds of trains*** with **a boolean field**.
- If the field is true, the instance represents a local train; otherwise, it is an express train.
- While a boolean field may work for a simple distinction like that, it really isn’t a good way to think about distinct kinds of trains.
- It also doesn’t scale to large problems, which offer ***a wide variety of trains with many distinct attributes***, e.g., city, local, regional, long distance, long distance express trains, and so on.
- In this section, we show how to use classes to represent distinct yet related kinds of information.

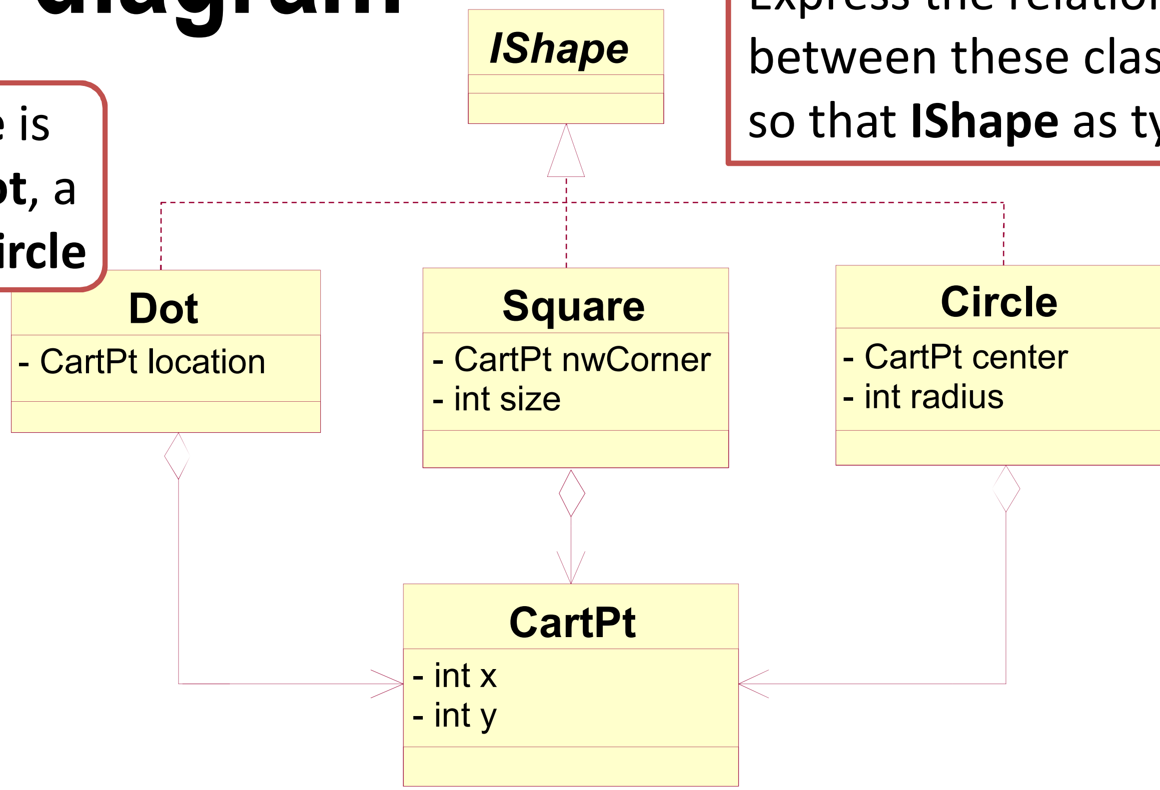
The Drawing Program

- Develop a drawing program that deals with at least three kinds of shapes: dots, squares, and circles.
  The shapes are located on a Cartesian grid whose origin is in the northwest.
  - A dot is located in the grid and is drawn as a small disk of a fixed size (3 pixels).
  - A square's location is specified via its north-west corner in the grid and its size.
  - A circle's essential properties are its center point and its radius.

Class diagram

Express the relationship between these classes, so that **IShape** as types of data

An **IShape** is one of a **Dot**, a **Square**, a **Circle**



- `IShape` is the name for a ***union of three classes of shapes***
  - it doesn't contribute any objects to the complete collection.
  - Its purpose is to represent the **complete collection of shapes**.
- `IShape` is supertype; `Dot`, `Square`, `Circle` is subclass

Java data definitions

```java
public interface IShape {
}
```

```java
public class Dot implements IShape {
   private CartPt location;
   public Dot(CartPt location) {
      this.location = location;
   }
}
```

```java
public class Square implements IShape {
   private CartPt nwCorner;
   private int size;
   public Square(CartPt nwCorner, int size) {
      this.nwCorner = nwCorner;
      this.size = size;
   }
}
```

```java
public class Circle implements IShape {
   private CartPt center;
   private int radius;
   public Circle(CartPt center, int radius) {
      this.center = center;
      this.radius = radius;
   }
}
```

Java data definitions

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

Test constructors

```java
public class ShapeTest extends TestCase {
   public void testConstructor() {
      //test for class CartPt
      CartPt p1 = new CartPt(4, 3);
      CartPt p2 = new CartPt(5, 12);

      // test  for class Dot
      IShape d1 = new Dot(p1);
      IShape d2 = new Dot(p2);

      //test for class Circle
      IShape c1 = new Circle(p1, 5);
      IShape c2 = new Circle(p2, 10);

      //test for class Square
      IShape s1 = new Square(p1, 5);
      IShape s2 = new Square(p2, 10);
   }
}
```

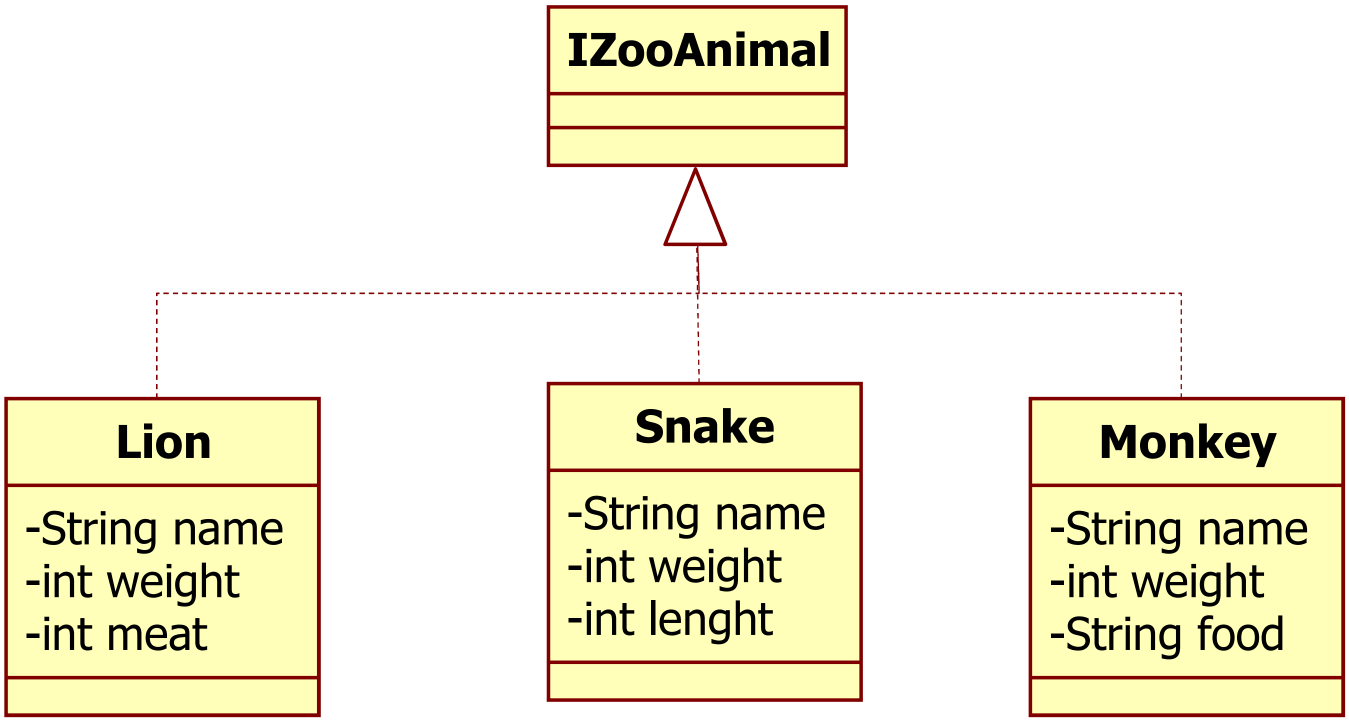
Types vs Classes

- A **class** is a general description of a collection of objects that provides a mechanism for constructing specific objects.
- An **interface** is a **uniform "face"** for several classes, which you sometimes wish to deal with as if it were one.
- A **type** describes for what kind of objects a variable or a parameter. In Java, a **type** is either the name of an **interface**, a **class**, or a **primitive type** **(`int`, `double`, `boolean`)**
- When we write: `IShape s;`
  - *s* has type ***`IShape`***, which means that it is a placeholder for some unknown (***`Dot`***, ***`Square`***, ***`Circle`***) shape.
- Similarly, when we introduce an example such as `IShape s = new Square(...)`
  - *s* has type ***`IShape`***, even though it stands for an instance of ***`Square`***.

Zoo example

- Develop a program that helps a zoo keeper take care of the animals in the zoo. For now the zoo has lions, snakes, and monkeys. Every animal has a name and weight. The zoo keeper also needs to know how much meat the lion eats per day, the length of each snake, and the favorite food for each monkey
- Examples:
  – The lion Leo weighs 300 pounds and eats 5 pounds of meat every day;
  – The snake Boa weighs 50 pounds and is 5 feet long;
  – The monkey George weighs 150 poundds and loves bananas.
  – The monkey Mina weighs 120 pounds and loves to eat kiwi

Class diagram



Java definitions

```java
public interface IZooAnimal {
}
```

```java
public class Lion
    implements IZooAnimal {
  private String name;
  private int weight;
  private int meat;
  public Lion(String name,
   int weight, int meat) {
    this.name = name;
    this.weight = weight;
    this.meat = meat;
  }
}
```

```java
public class Snake
    implements IZooAnimal {
  private String name;
  private int weight;
  private int length;
  public Snake(String name,
   int weight, int length) {
    this.name = name;
    this.weight = weight;
    this.length = length;
  }
}
```

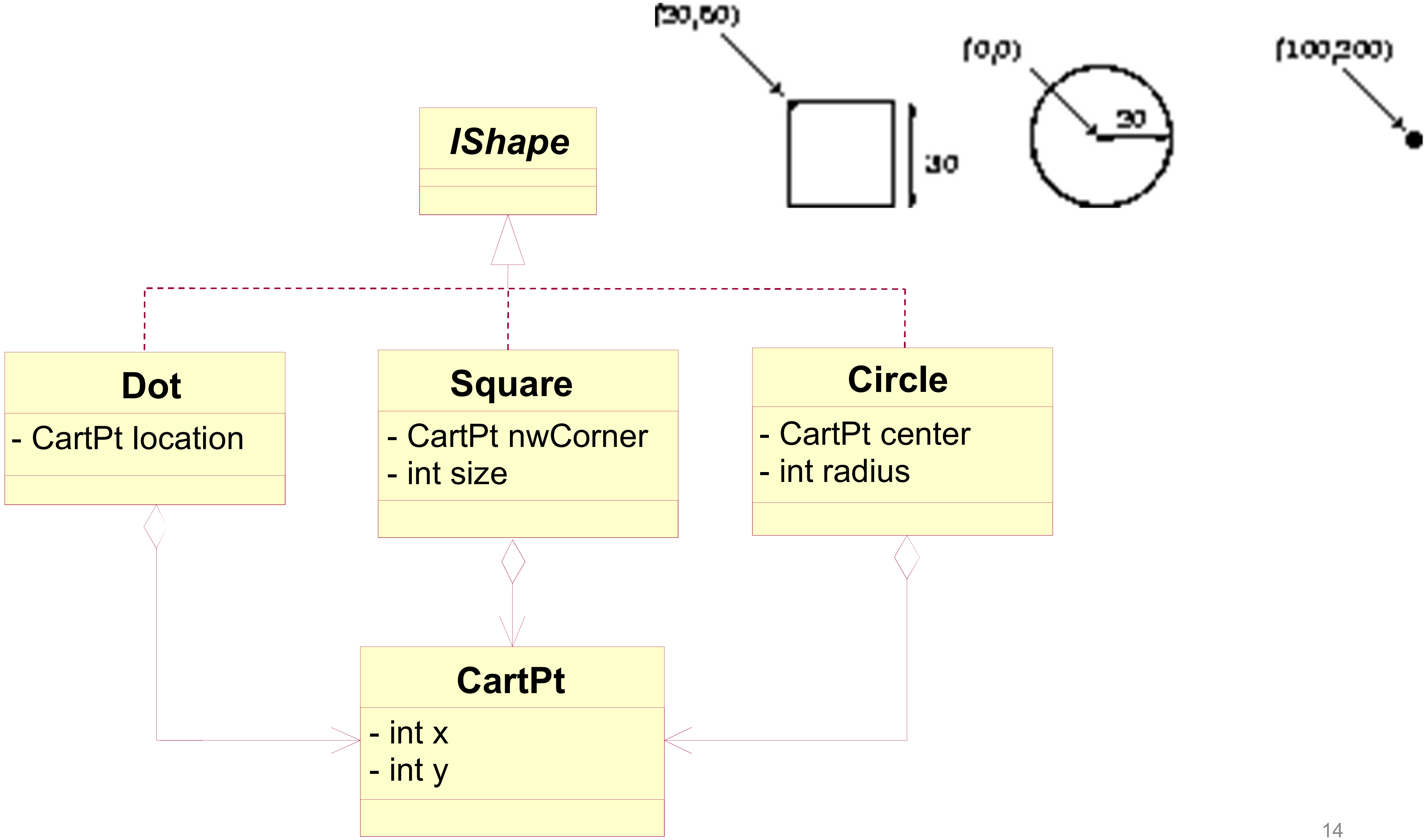
```java
public class Monkey
    implements IZooAnimal {
  private String name;
  private int weight;
  private String food;
  public Monkey(String name,
   int weight, String food) {
    this.name = name;
    this.weight = weight;
    this.food = food;
  }
}
```

Test constructor

```
public class AnimalTest extends TestCase {
   public void testConstructor() {
      // test for class Lion
      IZooAnimal leo = new Lion("Leo", 300, 5);
      IZooAnimal samba = new Lion("Samba", 200, 3);
      IZooAnimal Cleopon = new Lion("Cleopon", 250, 5);

      // test for class Snake
      IZooAnimal boa = new Snake("Boa", 50, 5);
      IZooAnimal mic = new Snake("Mic", 45, 4);
      IZooAnimal bu = new Snake("Bu", 55, 6);

      // test for class Monkey
      IZooAnimal george = new Monkey("George", 150, "banana");
      IZooAnimal mina = new Monkey("Mina", 120, "Kiwi");
      IZooAnimal slan = new Monkey("Slan", 100, "Kiwi");
   }
}
```

Design methods for unions of classes

Recall the Drawing Program

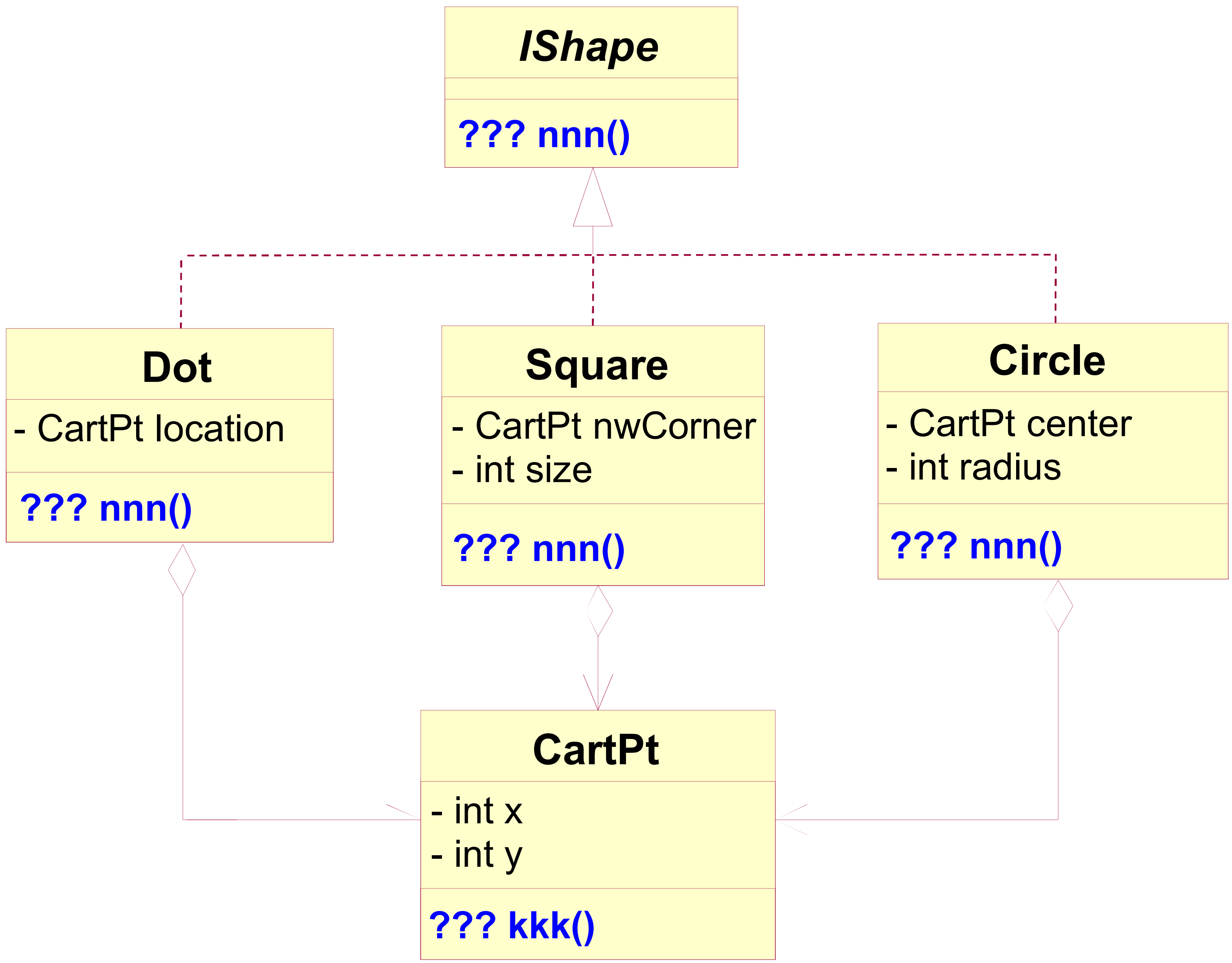


Requirements

1. Compute the *area* of a shape
2. Compute the *distance of a shape to the origin*
3. Determine *whether some point is inside the shape*
4. Compute the *bounding box* of a shape

- All of these methods clearly work with shapes in general but may have to compute different results depending on the concrete shape on which they are invoked
  - For example, a **`Dot`** has no true area; a **`Square`**'s area is computed differently from a **`Circle`**'s area
- In an object-oriented language, we can express this requirement with the addition of a method signature to the `IShape` interface

Add method for union of Shapes



kkk() Method Template of CartPt

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

  public ??? kkk() {
     …this.x…
     …this.y…
  }
}
```

nnn() method template of Shape

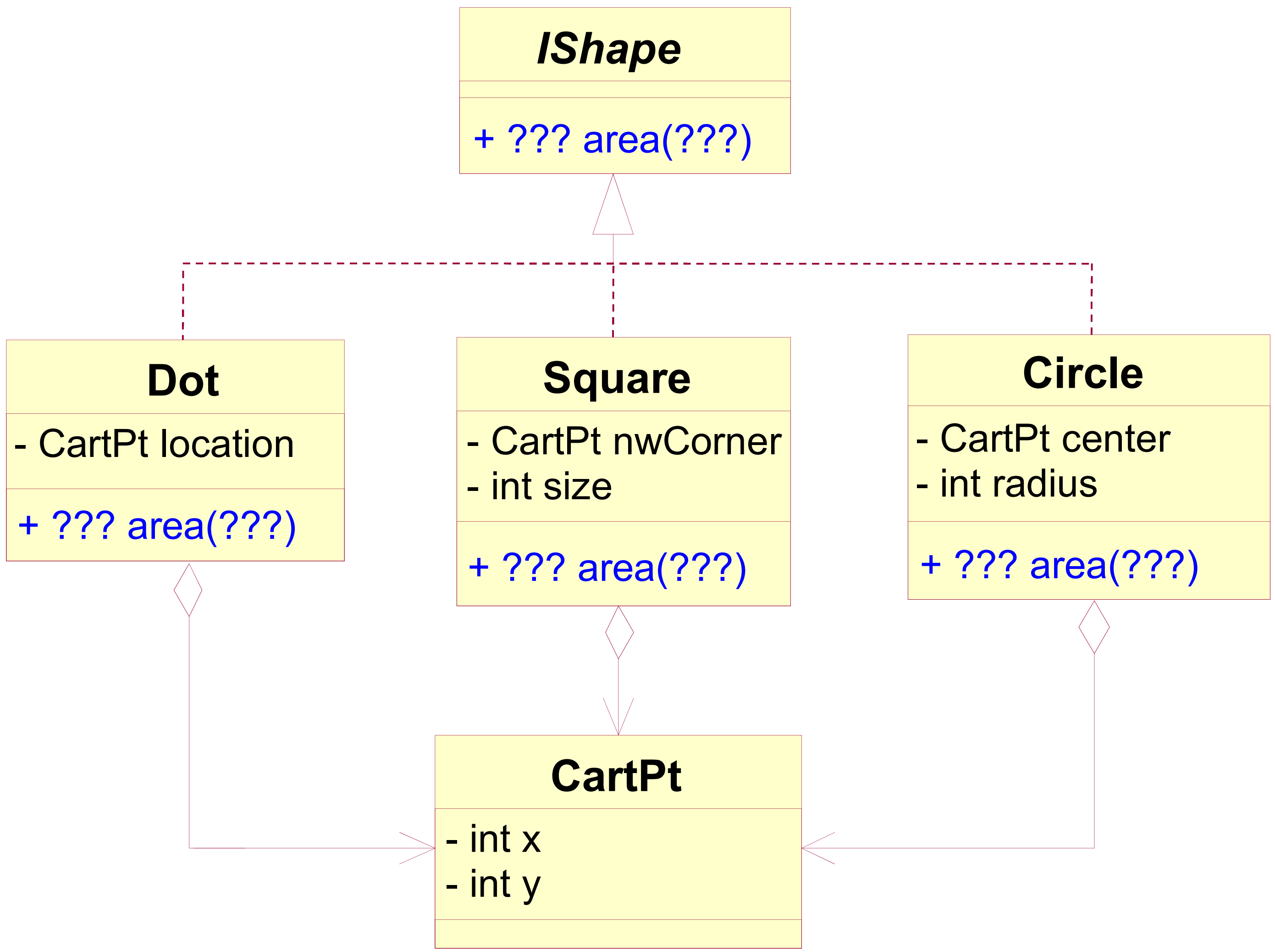
```
public interface IShape {
   public ??? nnn();
}
```

```
public class Dot
  implements IShape {
  private CartPt location;
  public Dot(CartPt location)
    this.location = location;
  }

  public ??? nnn() {
    ...this.location.kkk()...
  }
}
```

```
public class Square
  implements IShape {
  private CartPt nwCorner;
  private int size;
  public Square(
      CartPt nwCorner,
      int size) {
    this.nwCorner = nwCorner;
    this.size = size;
  }

  public ??? nnn() {
    ...this.nwCorner.kkk()...
    ...this.size...
  }
}
```

```
public class Circle
  implements IShape {
  private CartPt center;
  private int radius;
  public Circle(
      CartPt center,
      int radius) {
    this.center = center;
    this.radius = radius;
  }

  public ??? nnn() {
    ...this.center.kkk()...
    ...this.radius...
  }
}
```

1. Computing area of a Shape



Augmenting IShape area() purpose and signature

```
public interface IShape {
 // compute area of a shape
    public double area();
}
```

```
class Dot implements IShape {
   ...
   public double area() { ... }
}
```

```
class Square implements IShape {
   ...
   public double area() { ... }
}
```

```
class Circle implements IShape {
   ...
   public double area() { ... }
}
```

Examples

```
new Dot(new CartPt(4, 3)).area()
// should be 0.0
new Square(new CartPt(4, 3), 30).area()
// should be 900.0
new Circle(new CartPt(5, 5), 20).area()
// should be 1256.6...
```

Q: Implement the body of all `area()` methods

Implement `area()` method

```
// inside of Dot
public double area() {
    return 0.0;
}
```

```
// inside of Circle
public double area() {
    return Math.PI * this.radius * this.radius;
}
```

```
// inside of Square
public double area() {
    return this.size * this.size;
}
```

Unit Testing

```
public class ShapeTest extends TestCase {
   public void testArea() {
      assertEquals(new Dot(new CartPt(4, 3))
           .area(), 0.0, 0.001);
      assertEquals(new Square(new CartPt(4, 3), 30)
           .area(), 900, 0.001);
      assertEquals(new Circle(new CartPt(5, 5), 20)
           .area(), 1256.637, 0.001);

      IShape s1 = new Dot(new CartPt(4, 3));
      IShape s2 = new Square(new CartPt(4, 3), 30);
      IShape s3 = new Circle(new CartPt(5, 5), 20);
      assertEquals(s1.area(), 0.0, 0.001);
      assertEquals(s2.area(), 900, 0.001);
      assertEquals(s3.area(), 1256.637, 0.001);
  }
}
```

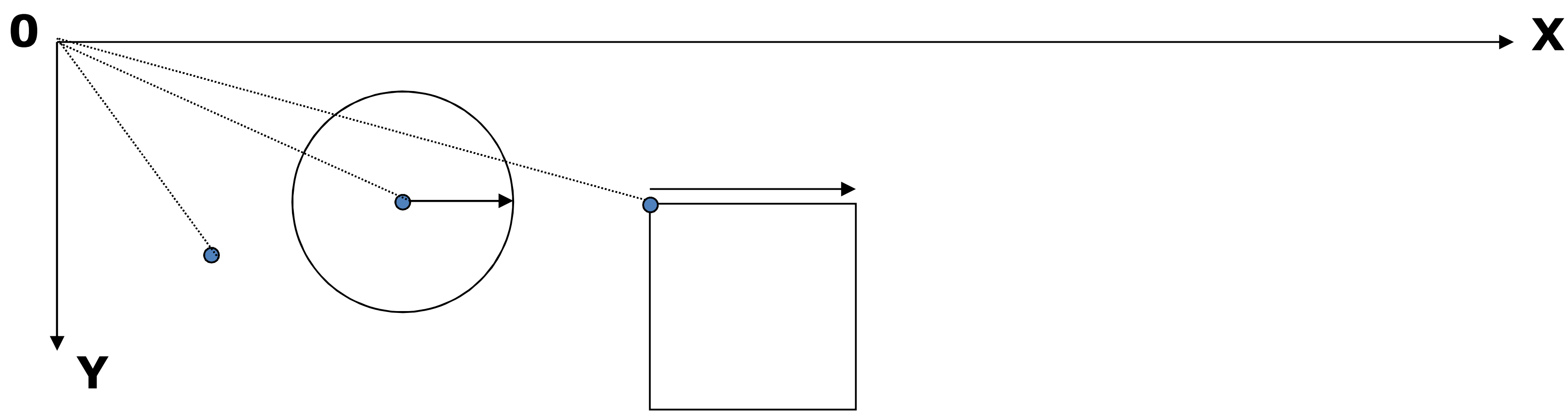
Polymorphism

- With the same call `area()`, but each *concrete subclass deal with it in difference way*.

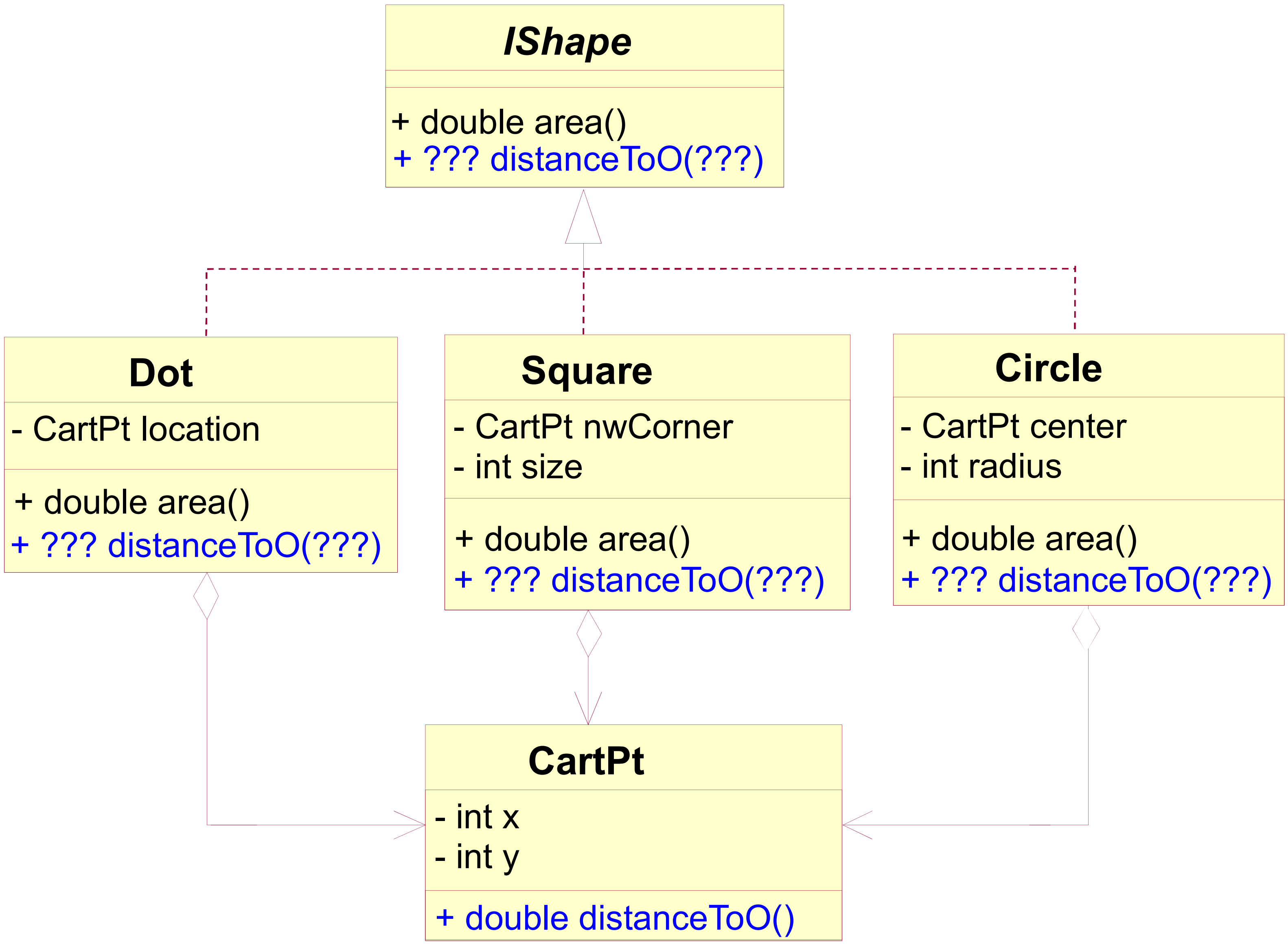
→ Polymorphism

2. Computing the distance of a shape to the origin

- What is the distance between a shape and the origin?



Add method to class diagram



distanceToO() purpose and signature

```
public interface IShape {
   // compute area of AShape
   public double area();

   // to compute the distance of this shape to the origin
   public double distanceToO();
}
```

Implement `distanceToO()`

```
// inside of Dot
public double distanceToO() {
   return this.location.distanceToO();
}
```

```
// inside of Square
public double distanceToO() {
   return this.nwCorner.distanceToO();
}
```

```
// inside of Circle
public double distanceToO() {
   return this.center.distanceToO();
}
```

distanceToO method in CartPt

```java
public class CartPt {
   private int x;
   private int y;

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

   // to compute the distance of this CartPt to the origin
   public double distanceToO() {
      return Math.sqrt(this.x * this.x + this.y * this.y);
   }
}
```

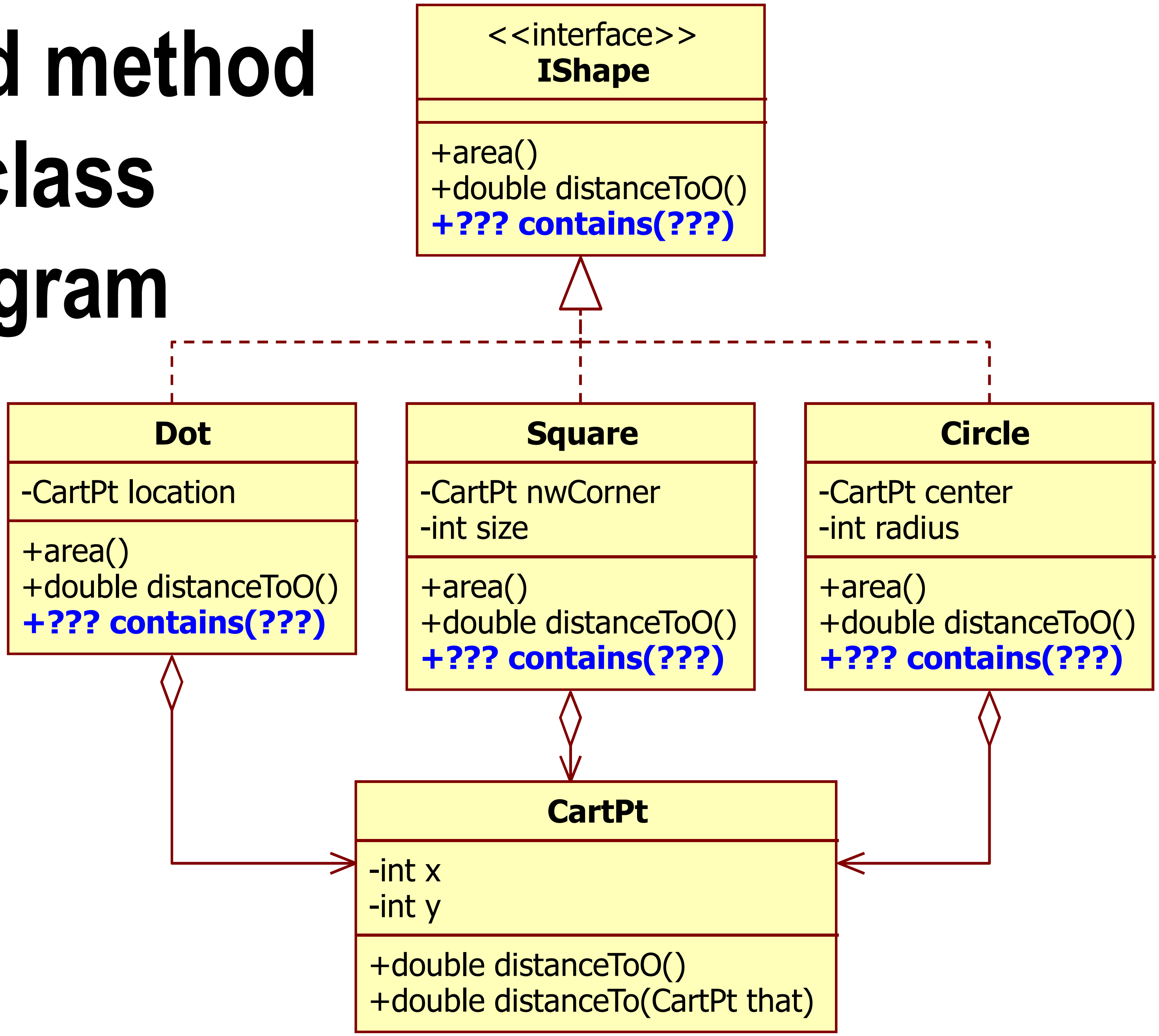
Unit Test

```
public class ShapeTest extends TestCase {
   ...

   public void testDistanceToO() {
      assertEquals(new Dot(new CartPt(4, 3))
         .distanceToO(), 5.0, 0.001);

      assertEquals(new Square(new CartPt(4, 3), 30)
         .distanceToO(), 5.0, 0.001);

      assertEquals(new Circle(new CartPt(12, 5), 20)
         .distanceToO(), 13.0, 0.001);
   }
}
```

3. Determining whether some point is inside the shape

- A given point is inside a DOT when its distance to this DOT is 0.
- a given point is inside a CIRCLE if its distance to the center of the CIRCLE is less than or equal the radius.
- A given point is inside a SQUARE when it is between two pairs of lines.

Add method to class diagram



`contains()` purpose and signature

```java
public interface IShape {
   // compute area of AShape
   public double area();

   // to compute the distance of this shape to the origin
   public double distanceToO();

   // is the given point is within the bounds
   // of this shape
   public boolean contains(CartPt point);
}
```

Examples

- ```
  new Dot(new CartPt(100, 200))
      .contains(new CartPt(100, 200)) // should be true
  ```
- ```
  new Dot(new CartPt(100, 200))
      .contains(new CartPt(80, 220))  // should be false
  ```
- ```
  new Square(new CartPt(100, 200), 40)
      .contains(new CartPt(120, 220)) // should be true
  ```
- ```
  new Square(new CartPt(100, 200), 40)
      .contains(new CartPt(80, 220))  // should be false
  ```
- ```
  new Circle(new CartPt(0, 0), 20)
      .contains(new CartPt(4, 3))     // should be true
  ```
- ```
  new Circle(new CartPt(0, 0), 10)
      .contains(new CartPt(12, 5))    // should be false
  ```

Domain Knowledge

- How to determine whether some point is inside the shape is a kind of knowledge called DOMAIN KNOWLEDGE
- To comprehend the domain knowledge, we sometimes look up in a book and in other situations we gather from experts

Implement `contains()`

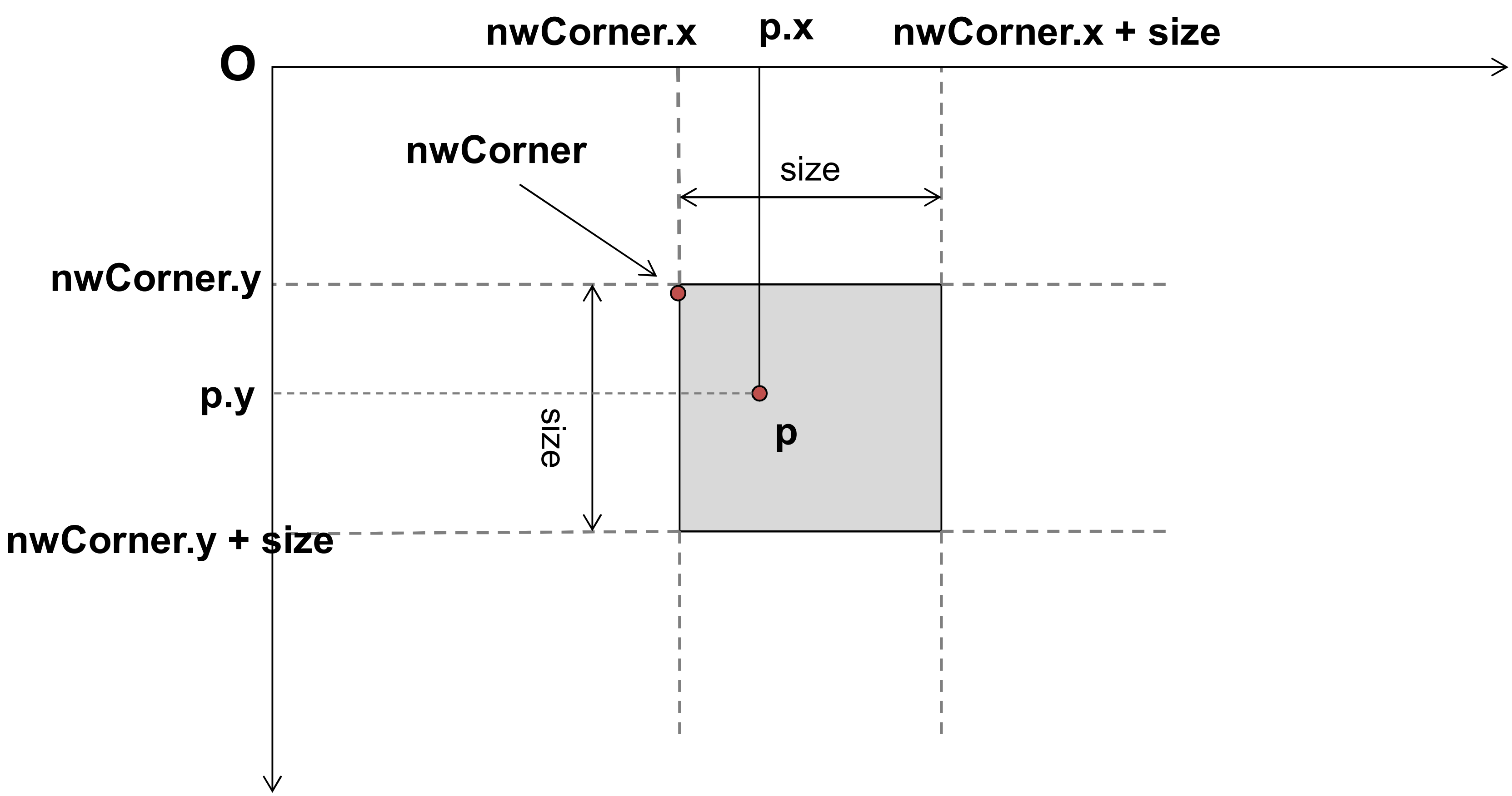
```
// inside of Dot
public boolean contains(CartPt point) {
   return this.location.distanceTo(point) == 0.0;
}
```

```
// inside of Circle
public boolean contains(CartPt point) {
   return this.center.distanceTo(point) <= this.radius;
}
```

distanceTo() in CartPt

```
public class CartPt {
   private int x;
   private int y;
   public CartPt(int x, int y) {
      this.x = x;
      this.y = y;
   }
   public double distanceToO() {
      return Math.sqrt(this.x * this.x + this.y * this.y);
   }

   // compute distance of this point to another point
   public double distanceTo(CartPt that) {
      double diffX = this.x - that.x;
      double diffY = this.y - that.y;
      return Math.sqrt(diffX * diffX + diffY * diffY);
   }
}
```

Implement `contains()` in `Square`



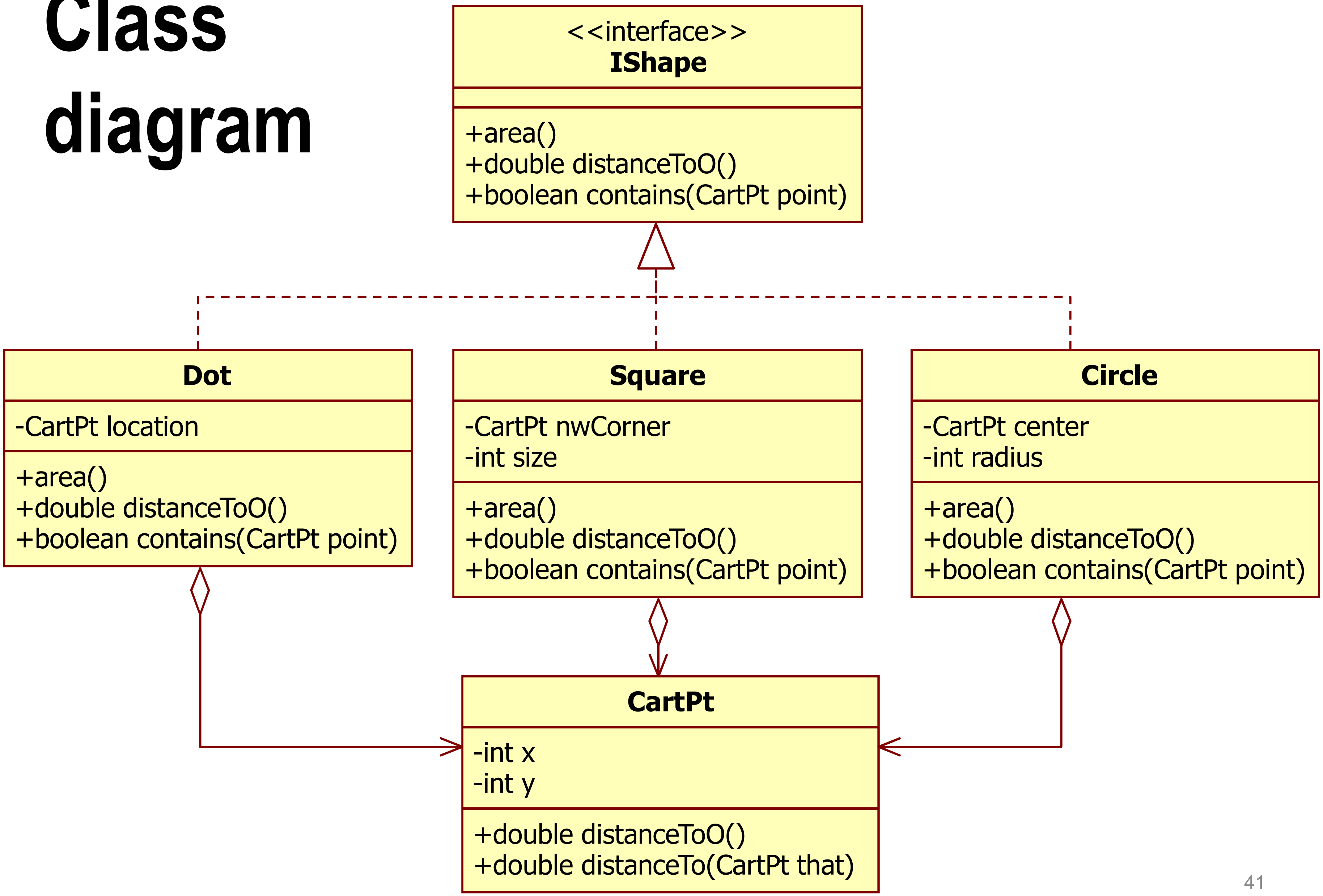
```java
// inside of Square
public boolean contains(CartPt point) {
   int nwx = this.nwCorner.getX();
   int nwy = this.nwCorner.getY();
   int px = point.getX();
   int py = point.getX();
   // return (px >= nwx && px <= nwx + this.size)
   //     && (py >= nwy && py <= nwy + this.size);
   return this.between(px, nwx, nwx + this.size)
       && this.between(py, nwy, nwy + this.size);
}
//-------------------------------------------------------------
private boolean between(int value, int low, int high) {
   return (low <= value) && (value <= high);
}
```

```java
// inside of CartPt
public class CartPt {
   private int x;
   private int y;
   public int getX() { return this.x; }
   public int getY() { return this.y; }
}
```

Unit test

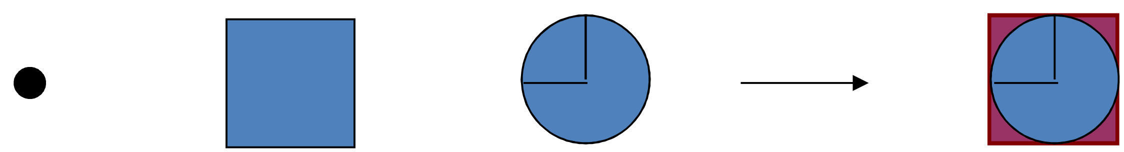
```
public class ShapeTest extends TestCase {
   public void testContain() {
      assertTrue(new Dot(new CartPt(100, 200))
                     .contains(new CartPt(100, 200)));
      assertFalse(new Dot(new CartPt(100, 200))
                     .contains(new CartPt(80, 220)));

      assertTrue(new Square(new CartPt(100, 200), 40)
                     .contains(new CartPt(120, 220)));
      assertFalse(new Square(new CartPt(100, 200), 40)
                     .contains(new CartPt(80, 220)));

      assertTrue(new Circle(new CartPt(0, 0), 20)
                     .contains(new CartPt(4, 3)));
      assertFalse(new Circle(new CartPt(0, 0), 10)
                     .contains(new CartPt(12, 5)));
   }
}
```

Class diagram

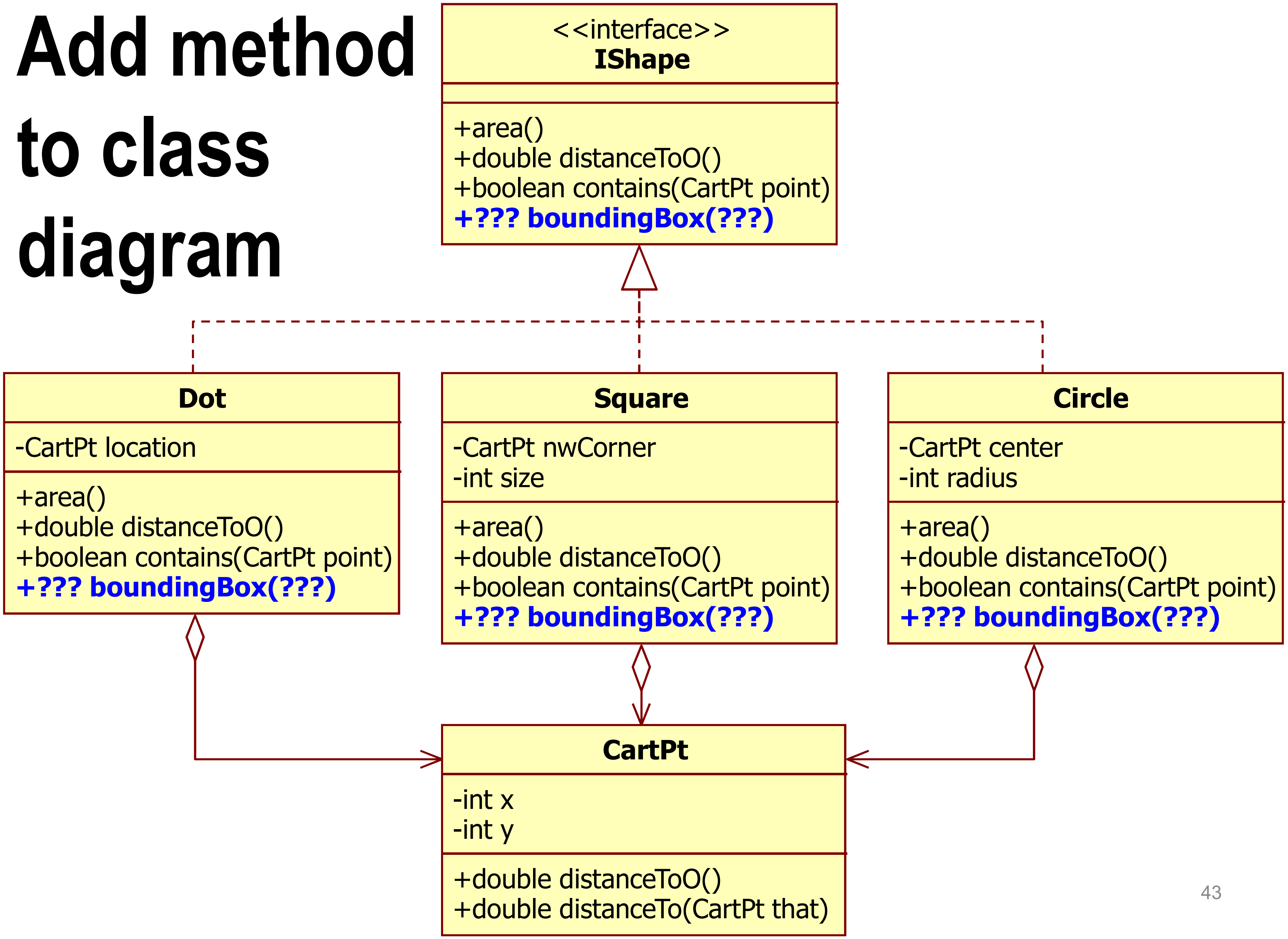


4. Computing the bounding box of a shape

- What is a Bounding Box?
  A bounding box is the smallest square that completely surrounds the given shape
- The bounding box for a `Square` is the given square itself.
- For a `Circle`, the bounding box is also a square,
  - its width and height are 2 * radius and
  - its northwest corner is one radius removed from the center of the circle in both directions.
- The bounding box for a `Dot` is a square with no extent.
  Mathematicians call this idea a special case



Add method to class diagram



boundingBox
purpose and signature

```
public interface IShape {
   // compute area of AShape
   public double area();

   // to compute the distance of this shape to the origin
   public double distanceToO();

   // is the given point is within the bounds
   // of this shape
   public boolean contains(CartPt point);

   // compute the bounding box for this shape
    public Square boundingBox();

}
```

Examples

```
new Dot(new CartPt(5, 5)).boundingBox()
// should be
new Square(new CartPt(5, 5), 0)

new Square(new CartPt(4, 3), 40).boundingBox()
// should be
new Square(new CartPt(4, 3), 40)

new Circle(new CartPt(10, 30), 20).boundingBox()
// should be
new Square(new CartPt(-10, 10), 40))
```

Implement `boundingBox()` method

inside of **Dot**

```
public Square boundingBox() {
    return new Square(this.location, 0);
}
```

inside of **Square**

```
public Square boundingBox() {
    return new Square(this.nwCorner, this.size);
}
```

boundingBox method in Circle

```
// Not delegation
public Square boundingBox() {
   return new Square(new CartPt(this.center.getX()-this.radius,
              this.center.getY()-this.radius), this.radius * 2);
}
```

```
// Delegation to center translate (-radius, -radius) offset
public Square boundingBox() {
   return new Square(this.center.translate(
          -this.radius, -this.radius), this.radius * 2);
}
```

inside of CartPt

```
// translate this point to dX, dY distance
public CartPt translate(int dX, int dY) {
   return new CartPt(this.x + dX, this.y + dY);
}
```

Unit test

```
public class ShapeTest extends TestCase {
   ...

   public void testBoundingBox(){
      assertEquals(new Dot(new CartPt(4, 3)).boundingBox(),
                   new Square(new CartPt(4, 3), 0));

      assertEquals(new Square(new CartPt(4, 3), 30).boundingBox(),
                   new Square(new CartPt(4, 3), 30));

      assertEquals(new Circle(new CartPt(10, 30), 20).boundingBox(),
                   new Square(new CartPt(-10, 10), 40));
   }
}
```

equals method

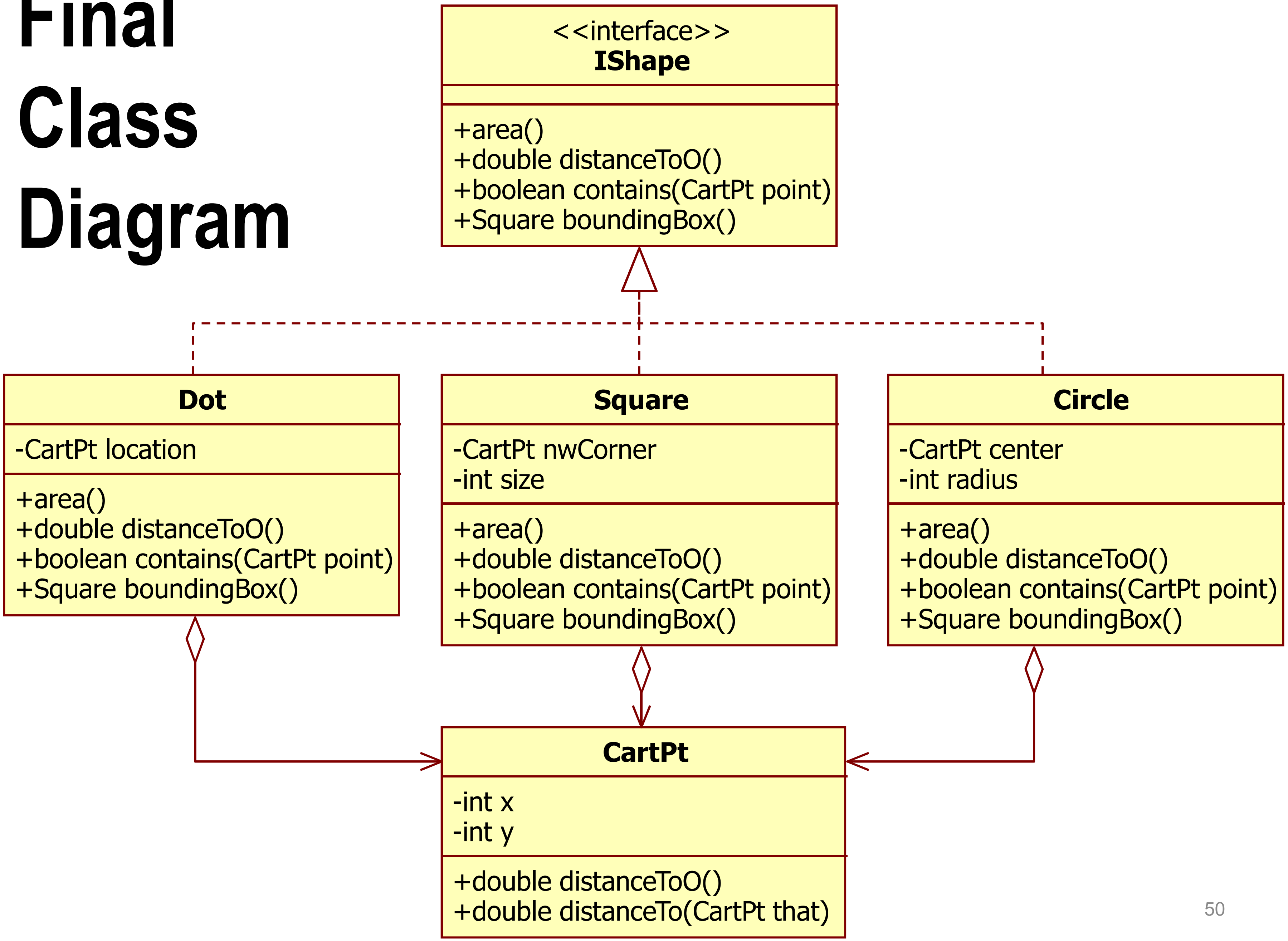
inside of Square class

```
public boolean equals(Object obj) {
   if (null==obj || !(obj instanceof Square))
      return false;
   else {
      Square that = (Square) obj;
      return (this.nwCorner.equals(that.nwCorner)
           && this.size == that.size);
   }
}
```

inside of CartPt class

```
public boolean equals(Object obj) {
  if (null==obj || !(obj instanceof CartPt))
    return false;
  else {
    CartPt that = (CartPt) obj;
    return (this.x == that.x) && (this.y == that.y);
  }
}
```

Final Class Diagram



Abstract with Class Common Data

Similarities in Classes

- **Similarities** among classes are common in unions.
- Several variants often contain **identical field** definitions. Beyond fields, variants also sometimes share identical or **similar method** definitions.
- Our first union is a representation of simple geometric shapes. All three classes implement ***IShape***. Each contains a ***CartPt*** typed field that specifies where the shape is located.

`public class Dot`
`  implements IShape {`
`  private CartPt location;`
`  ...`
`}`
	`public class Square`
	`  implements IShape {`
	`  private CartPt nwCorner;`
	`  ...`
	`}`
		`public class Circle`
		`  implements IShape {`
		`  private CartPt center;`
		`  ...`
		`}`

Common Fields, Superclasses

- In OOP, classes cannot only inherit from interfaces, they can also inherit from other classes.
- This suggests the introduction of a **common superclass** of *Dot*, *Square*, and *Circle* that represents the commonalities of geometric shapes:

```
public class AShape implements IShape {
  private CartPt location;
  public AShape(CartPt location) {
     this.location = location;
  }
}
```

- Here the class represents two commonalities: the ***CartPt*** field and the **implements** specification

Inheritance

- If we make *Dot* an extension of *AShape*, it inherits the *CartPt* field and the obligation to implement *IShape*:

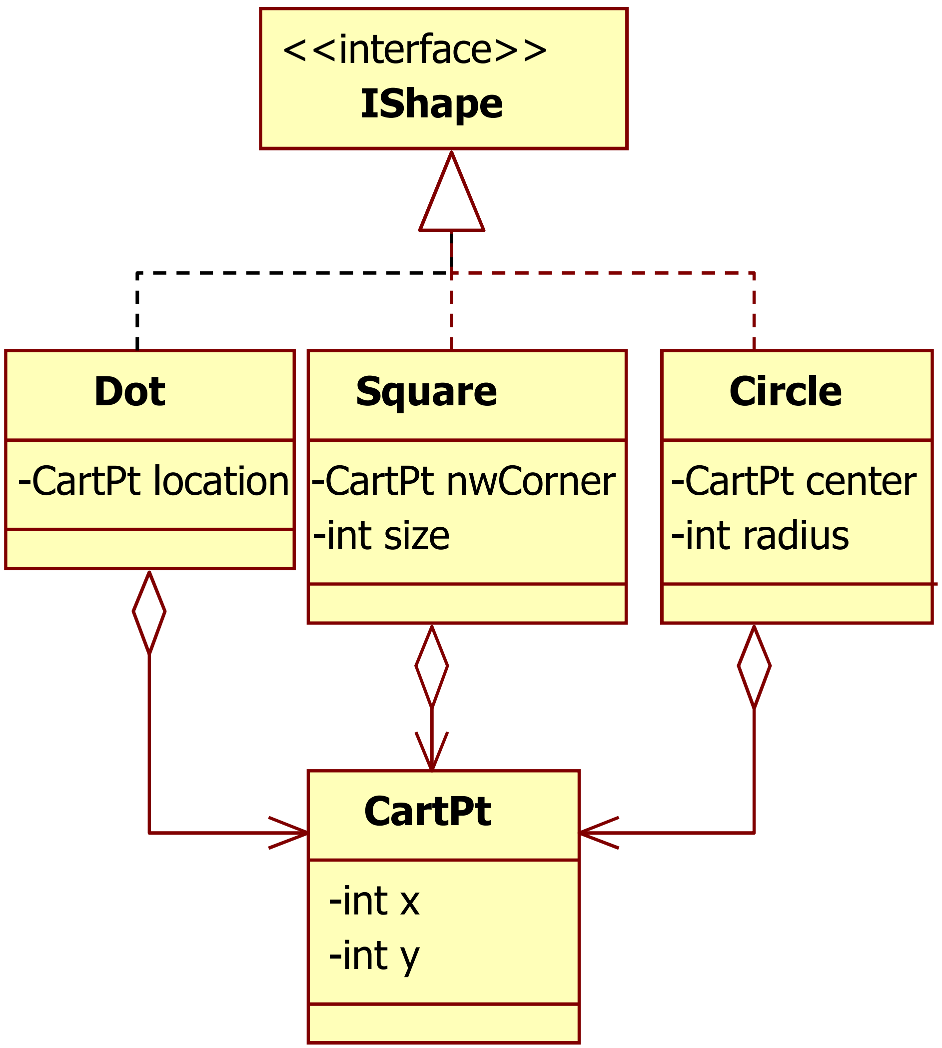
```
public class Dot
   extends AShape {
```

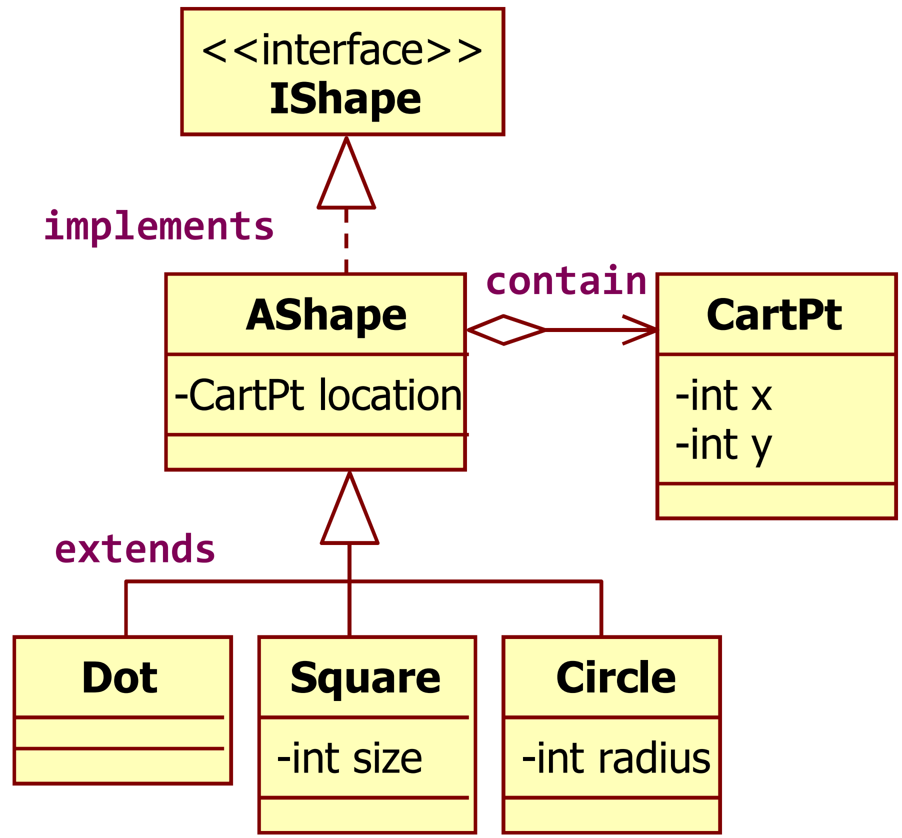
```
public class Square
   extends AShape {
```

```
public class Circle
   extends AShape {
```

- In general, the phrase *B* **extends** A says that *B* inherits all of *A*'s features (fields, methods, and **implements** obligations), which include those that *A* inherited.
  - *A* is the SUPERCLASS and *B* is the SUBCLASS;
  - we also say that *B* REFINES *A* or that *B* is DERIVED from *A.*
- Tend to attribute the commonalities to the superclass, and the differences to the subclasses.

Revised class diagram





Subclasses inherits the ***Location*** field and obligation to implement ***IShape*** from ***AShape*** superclass

Java data definitions

```
public interface IShape {
}
```

```
public class AShape implements IShape {
  private CartPt location;
}
```

```
public class Dot extends AShape {
}
```

```
public class Square extends AShape {
  private int size;
}
```

```
public class Circle extends AShape {
  private int radius;
}
```

Contructor of Shape

Two constructor format of **Square**

```
public class AShape implements IShape {
    protected CartPt location;
}
```

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

access **protected location** field inherits form **AShape**

```
public class AShape implements IShape {
    private CartPt location;
    public AShape(CartPt location) {
        this.location = location;
    }
}
```

Can't to access private **location** field, so Call constructor of **AShape** superclass

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

Contructor of Shape (format 1)

```
public class AShape implements IShape {
   protected CartPt location;
}
```

```
public class Dot extends AShape {
   public Dot(CartPt location) {
      this.location = location;
   }
}
```

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

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

Subclasses can access **protected location** common field inherits form **AShape**

Contructor of Shape (format 2)

```
public class AShape implements IShape {
    private CartPt location;
    public AShape(CartPt location) {
        this.location = location;
    }
}
```

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

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

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

Subclasses call constructor of **AShape** superclass

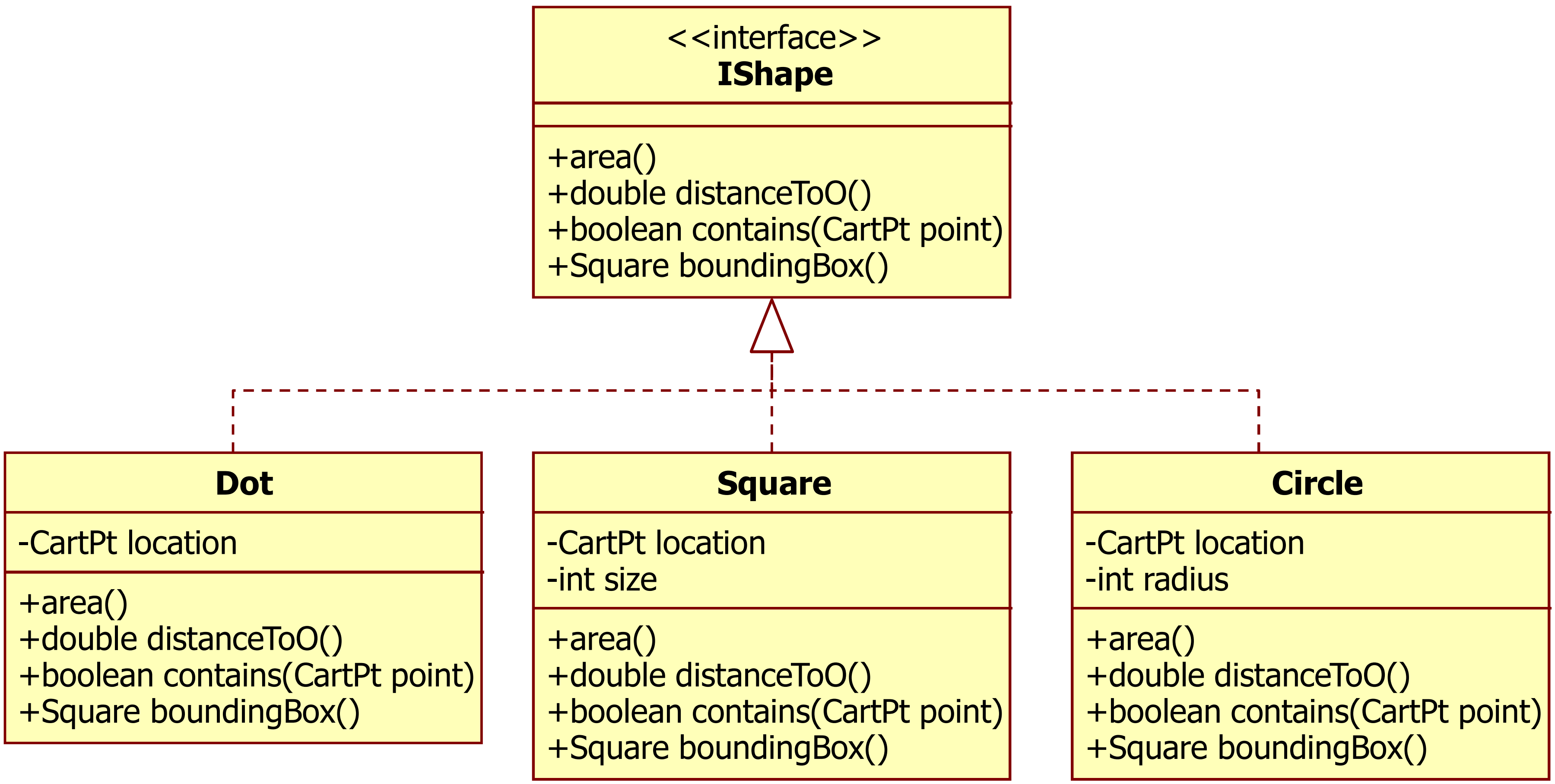
Test constructors

```java
public class ShapeTest extends TestCase {
   public void testConstructor() {
      //test for class CartPt
      CartPt p1 = new CartPt(4, 3);
      CartPt p2 = new CartPt(5, 12);

      // test  for class Dot
      IShape d1 = new Dot(p1);
      IShape d2 = new Dot(p2);

      //test for class Circle
      IShape c1 = new Circle(p1, 5);
      IShape c2 = new Circle(p2, 10);

      //test for class Square
      IShape s1 = new Square(p1, 5);
      IShape s2 = new Square(p2, 10);
   }
}
```

Abstract Classes, Abstract Methods

Methods of union of shape

- We designed several methods for plain shapes, including *area()*, *distanceToO()*, *contains()*, and *boundingBox()*



Abstract Method

- When we add `AShape` to the class hierarchy for
  - Collecting the commonalities of the concrete shapes
  - Implements **`IShape`** so that we wouldn't have to repeat this statement again for all the classes that extend **`AShape`**.
- So `AShape` must implement `area`, `distanceToO`, `contains`, and `boundingBox` what `IShape` specifies
- But implementing methods such as `area()` is different for each subclass.
- ***Solution***: Add `abstract` methods to the `abstract AShape` class

Abstract Method and Class

- An `abstract` method is just like a method signature in an interface, preceded by the keyword `abstract`.
- An `abstract` method doesn't have to define the method and shifts the responsibility to subclasses
- It also makes no sense to create instances of the `AShape` class, because:
  - All instances of `AShape` are instances of either `Dot`, `Square`, or `Circle`
  - And it doesn't implement all of the methods from its interface yet.
- We make the entire `AShape` class `abstract`.

Abstract Method and Class

```java
public interface IShape {
  // compute area of AShape
  public double area();

  // to compute the distance of
  // this shape to the origin
  public double distanceToO();

  // is the given point is within
  // the bounds of this shape
  public boolean
      contains(CartPt point);

  // compute the bounding box
  // for this shape
  public Square boundingBox();
}
```

It also makes no sense to create instances of the ***AShape*** class, we make the entire class **abstract**

```java
public abstract class AShape
         implements IShape {
  protected CartPt location;

  public abstract double area();
  public abstract double distanceToO();
  public abstract boolean
      contains(CartPt point);
  public abstract Square boundingBox();
}
```

An ***ABSTRACT*** method is a **method signature** and doesn't define the method, shifts the responsibility to subclasses

Subclasses define methods

```
public class Dot
  extends AShape {
  ...

  public double area() {
    return 0;
  }

  public double
    distanceToO() {
    return this.location
        .distanceToO();
  }
  ...
}
```

```
public class Square
  extends AShape {
  private int size;
  ...

  public double area() {
    return this.size *
           this.size;
  }

  public double
    distanceToO() {
    return this.location
        .distanceToO();
  }
  ...
}
```

```
public class Circle
  extends AShape {
  private int radius;
  ...

  public double area() {
    return Math.PI *
         this.size *
         this.size;
  }

  public double
    distanceToO() {
    return this.location
        .distanceToO();
  }
  ...
}
```

Lifting Methods, Inheriting Methods

- If all concrete subclasses of a union contain identical method definitions, we must lift them to the abstract class.
- Example: `distanceToO()` method in union of shapes

```
public interface IShape {
  // to compute the distance of
  // this shape to the origin
  public double distanceToO();
  ...
}
```

```
public abstract class AShape
       implements Ishape {
  private CartPt location;
  public abstract double distanceToO();
}
```

```
public class Dot
  extends AShape {
  public double
    distanceToO() {
    return
this.location
       .distanceToO();
  }
}
```

```
public class Square
  extends AShape {
  public double
    distanceToO() {
    return
this.location
       .distanceToO();
  }
}
```

```
public class Circle
  extends AShape {
  public double
    distanceToO() {
    return
this.location
       .distanceToO();
  }
}
```

Lifting `distanceToO()` method to the abstract `AShape` class

- The `distanceToO` method was designed identically in all the variants of a union with a common `AShape` superclass
- We can replace the `abstract` method in the `AShape` with the method definition from the variants and delete the methods from `Dot`, `Square`, and `Circle`. The lifted `distanceToO` method in is now available in all three subclasses

```
public interface IShape {
  // to compute the distance of
  // this shape to the origin
  public double distanceToO();
  ...
}
```

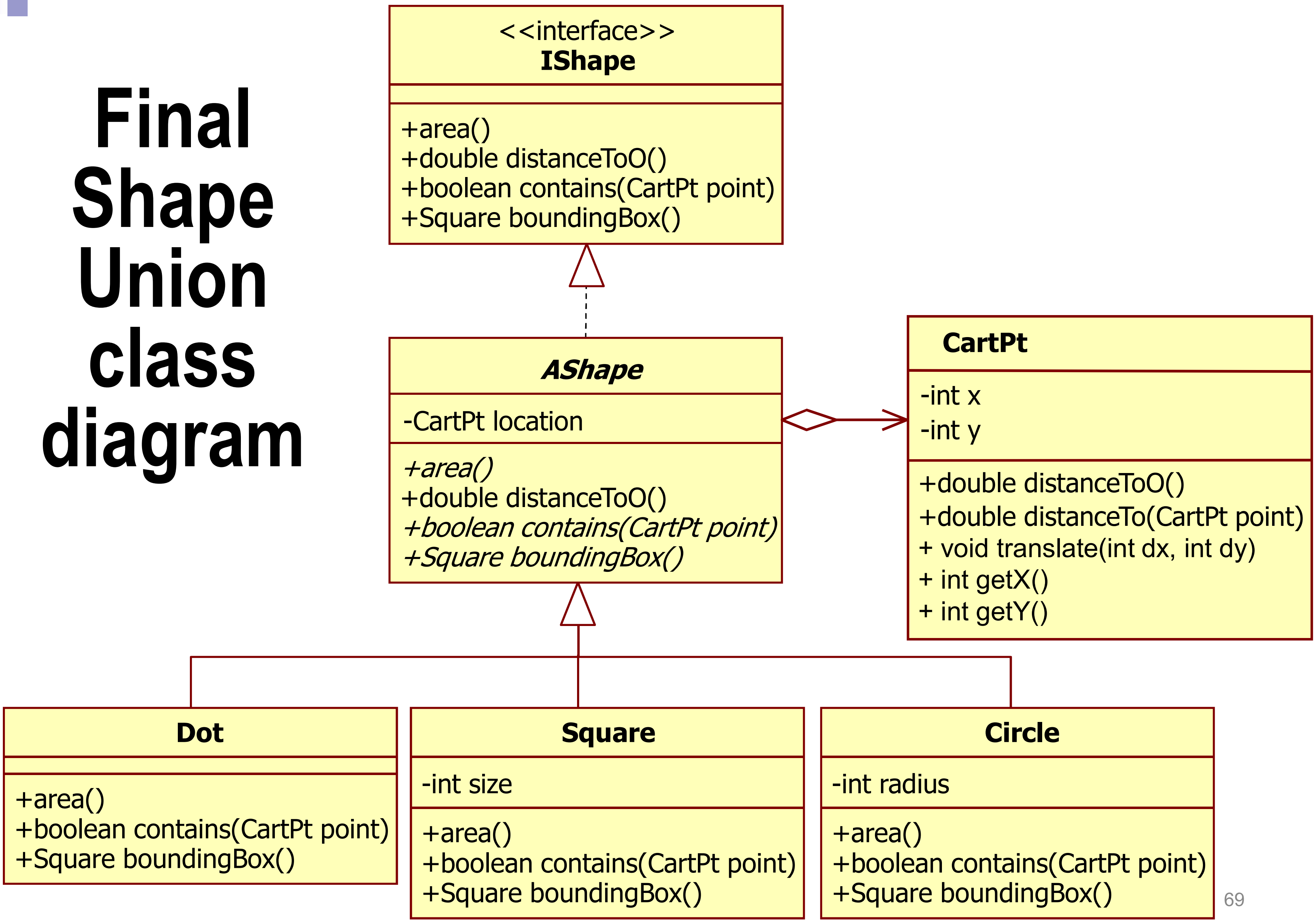
```
public abstract class AShape {
   private CartPt location;
   public double distanceToO() {
      return
this.location.distanceToO();
   }
}
```

```
public class Dot
  extends AShape {
   ...
}
```

```
public class Square
  extends AShape {
   ...
}
```

```
public class Circle
  extends AShape {
   ...
}
```

Final Shape Union class diagram



Keyword

- `interface`
  - Type of class
- `abstract` in front of a class indicates
  - The class is abstract.
  - there are no instances of this class.
    - can not use `new` operator to create an object of this class.
- `extends`
  - makes a refinement or an extension of the class, therefore the subclass INHERITS all of the superclass 's fields and methods.
- `implements`
  - makes a class is belong to interface type, and the class must implement all methods that the interface specifies.

`protected` attribute and method

- `protected`: ***the class itself and its subclass can access this attribute / method*.**

- **Q**: Review `public` and `private` modifiers for attribute and method.
  - `public`: Classes in all packages can see this attribute method.
  - `private`: the class itself can access this attribute and method.
  - `None modifier`: Classes in the same package can access attribute and method.

Modifiers for class

- `None modifier`: Classes in the same package can see this class.

- `public`: Classes in all packages can see this class.

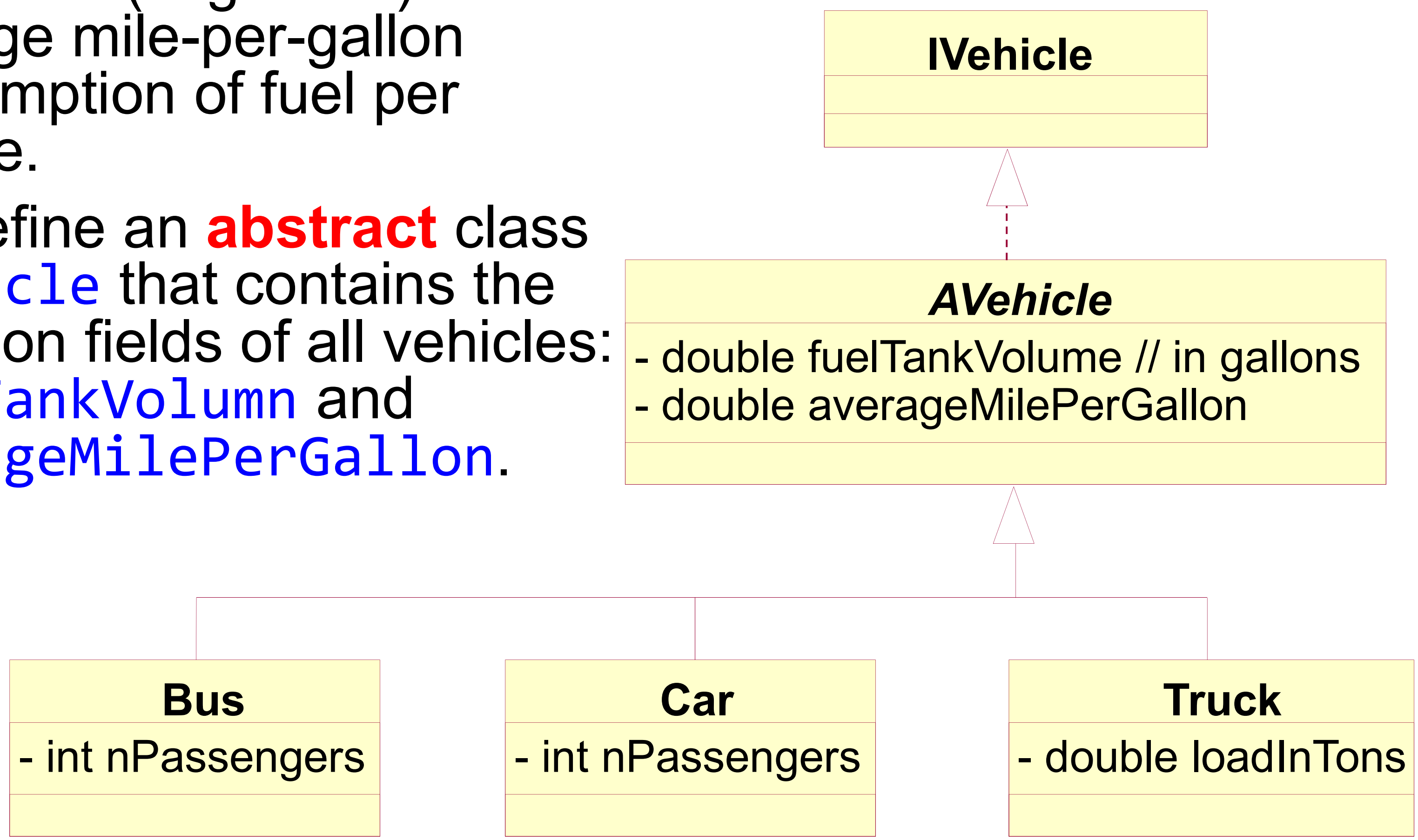
The Fuel Consumption Problem

Problem Statement

- A school district needs to manage the fuel consumption for its fleet of vehicles, which includes school busses, cars, and trucks.
- Each vehicle has a fuel tank of some size (in gallons).
- The district also knows the average mile-per-gallon consumption of fuel per vehicle.
- The fuel consumption for cars and busses depends on the number of passengers the vehicle carries; the fuel consumption of a truck increases with its load (in tons)

Class Diagram

- All vehicles has a fuel tank of some size (in gallons) and average mile-per-gallon consumption of fuel per vehicle.
- We define an **abstract** class `AVehicle` that contains the common fields of all vehicles: `fuelTankVolumn` and `averageMilePerGallon`.



Java data definitions

```java
public interface IVehicle {
}
```

```java
public abstract class AVehicle implements IVehicle {
   protected double fuelTankVolume; // in gallons
   protected double averageMilePerGallon;
   protected AVehicle(double fuelTankVolume,
                      double averageMilePerGallon) {
      this.fuelTankVolume = fuelTankVolume;
      this.averageMilePerGallon = averageMilePerGallon;
   }
}
```

Java data definitions

```
public class Bus extends AVehicle {
   private int nPassengers;
   public Bus(double fuelTankVolume,
             double averageMilePerGallon, int nPassengers ) {
      super(fuelTankVolume, averageMilePerGallon);
      this.nPassengers = nPassengers;
   }
}
```

```
public class Car extends AVehicle {
   private int nPassengers;
   public Car(double fuelTankVolume,
             double averageMilePerGallon, int nPassengers ) {
      super(fuelTankVolume, averageMilePerGallon);
      this.nPassengers = nPassengers;
   }
}
```

```
public class Truck extends AVehicle {
   private double loadInTons;
   public Bus(double fuelTankVolume,
             double averageMilePerGallon, double loadInTons) {
      super(fuelTankVolume, averageMilePerGallon);
      this.loadInTons = loadInTons;
   }
}
```

Examples

```
IVehicle c1 = new Car(15.0, 25.0, 1);

IVehicle t1 = new Truck(120., 6.0, 0.5);

IVehicle b1 = new Bus(60.0, 10.0, 20);
```

Requirement

- The manager needs to know how much it costs to refuel a vehicle with empty fuel tank at the current fuel prices so that the district can create estimates for the gas budget
- **Q:** Improve the current class diagram and give more examples

`refuelCost()` method signature

```java
public interface IVehicle {
   // Compute how much it costs to refuel this vehicle
   // with empty fuel tank at the current fuel prices
   public double refuelCost(double costPerGallon);
}
```

```java
public abstract class AVehicle implements IVehicle {
   protected double fuelTankVolume; // in gallons
   protected double averageMilePerGallon;
   protected AVehicle(double fuelTankVolume,
                      double averageMilePerGallon) {
      this.fuelTankVolume = fuelTankVolume;
      this.averageMilePerGallon = averageMilePerGallon;
   }

   public abstract double refuelCost(double costPerGallon);
}
```

More Examples

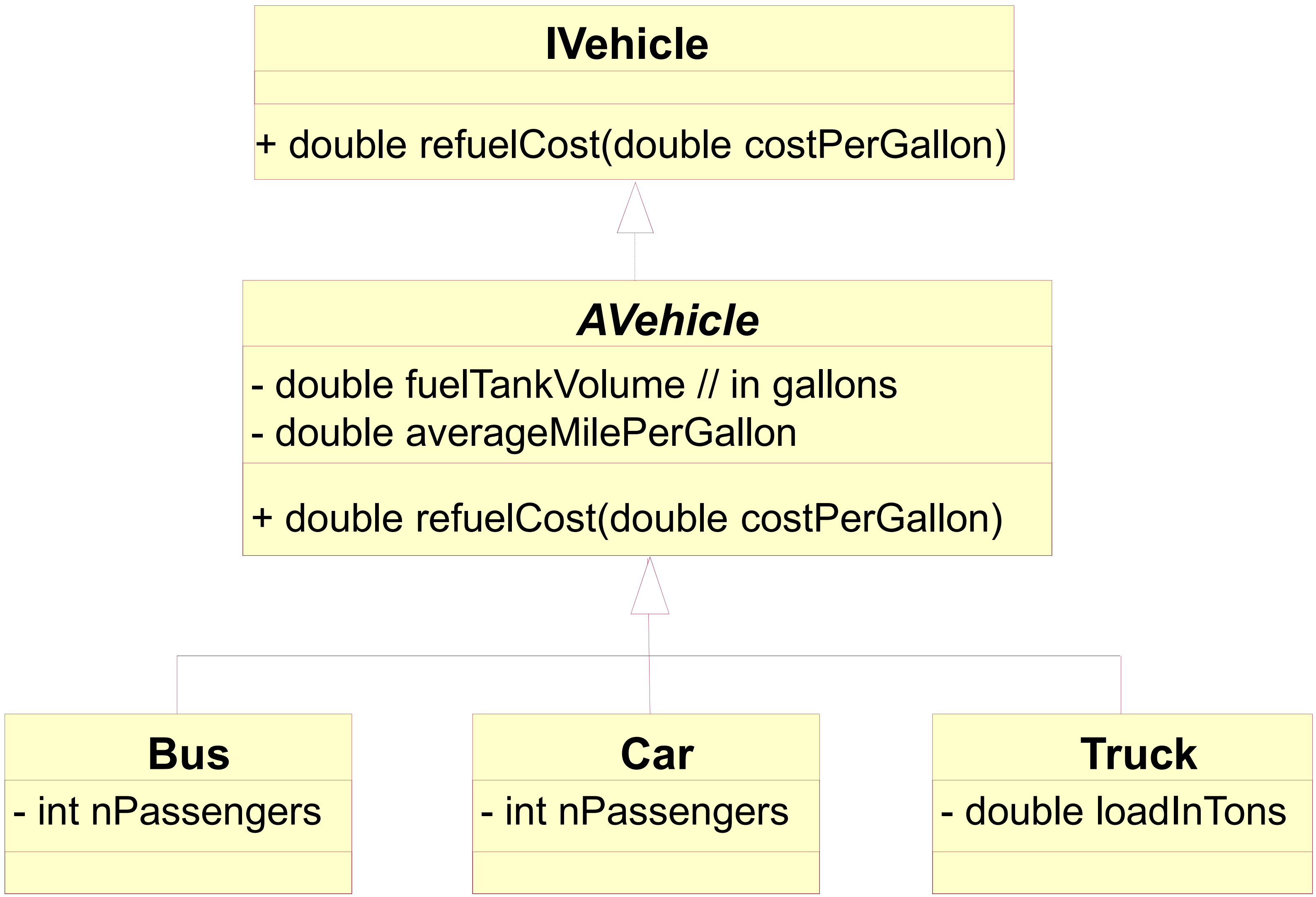
```
IVehicle b1 = new Bus(60.0, 10.0, 20);
IVehicle c1 = new Car(15.0, 25.0, 1);
IVehicle t1 = new Truck(120., 6.0, 0.5);

b1.refuelCost(2.00)
// should be 120.0

c1.refuelCost(2.00)
// should be 30.0

t1.refuelCost(2.00)
// should be 240.0
```

Implementation of `refuelCost()`

- Since three subclasses have the same implementation for **`refuelCost()`**, we could move this method to the superclass. This means **`refuelCost()`** now in the **`AVehicle`** class will not be abstract any more

```
public abstract class AVehicle implements IVehicle {
   private double fuelTankVolume; // in gallons
   private double averageMilePerGallon;
   protected AVehicle(double fuelTankVolume,
                      double averageMilePerGallon) {
      this.fuelTankVolume = fuelTankVolume;
      this.averageMilePerGallon = averageMilePerGallon;
   }
   public double refuelCost(double costPerGallon) {
      return costPerGallon * this.fuelTankVolume;
   }
}
```

Improved Class Diagram



One More Requirement

- The manager wants to compute the projected fuel consumption for a specific trip so that the various departments can get a proper projection for the cost of the transportation services. For busses, the fuel consumption increases by 1% with each passenger. For a car, the fuel consumption increases by 10% with each passenger. For truck, one ton of load increases the fuel consumption by 5%
- Notice that the fuel consumption is measured in miles per gallon
- **Q:** Improve the current class diagram and give more examples

fuelConsumption() signature

```java
public interface IVehicle {
   public double refuelCost(double costPerGallon);
   // compute the fuel consumption of this vehicle
   public double fuelConsumption();
}
```

```java
public abstract class AVehicle implements IVehicle {
   private double fuelTankVolume; // in gallons
   private double averageMilePerGallon;
   protected AVehicle(double fuelTankVolume,
                      double averageMilePerGallon) {
      this.fuelTankVolume = fuelTankVolume;
      this.averageMilePerGallon = averageMilePerGallon;
   }
   public double refuelCost(double costPerGallon) {
      return costPerGallon * this.fuelTankVolume;
   }
   public abstract double fuelConsumption();
}
```

More Examples

```
IVehicle b1 = new Bus(60.0, 10.0, 20);
IVehicle c1 = new Car(15.0, 25.0, 1);
IVehicle t1 = new Truck(120., 6.0, 0.5);

b1.fuelConsumption()
// should be 8

c1.fuelConsumption()
// should be 22.5

t1.fuelConsumption()
// should be 5.85
```

`fuelConsumption()` implement

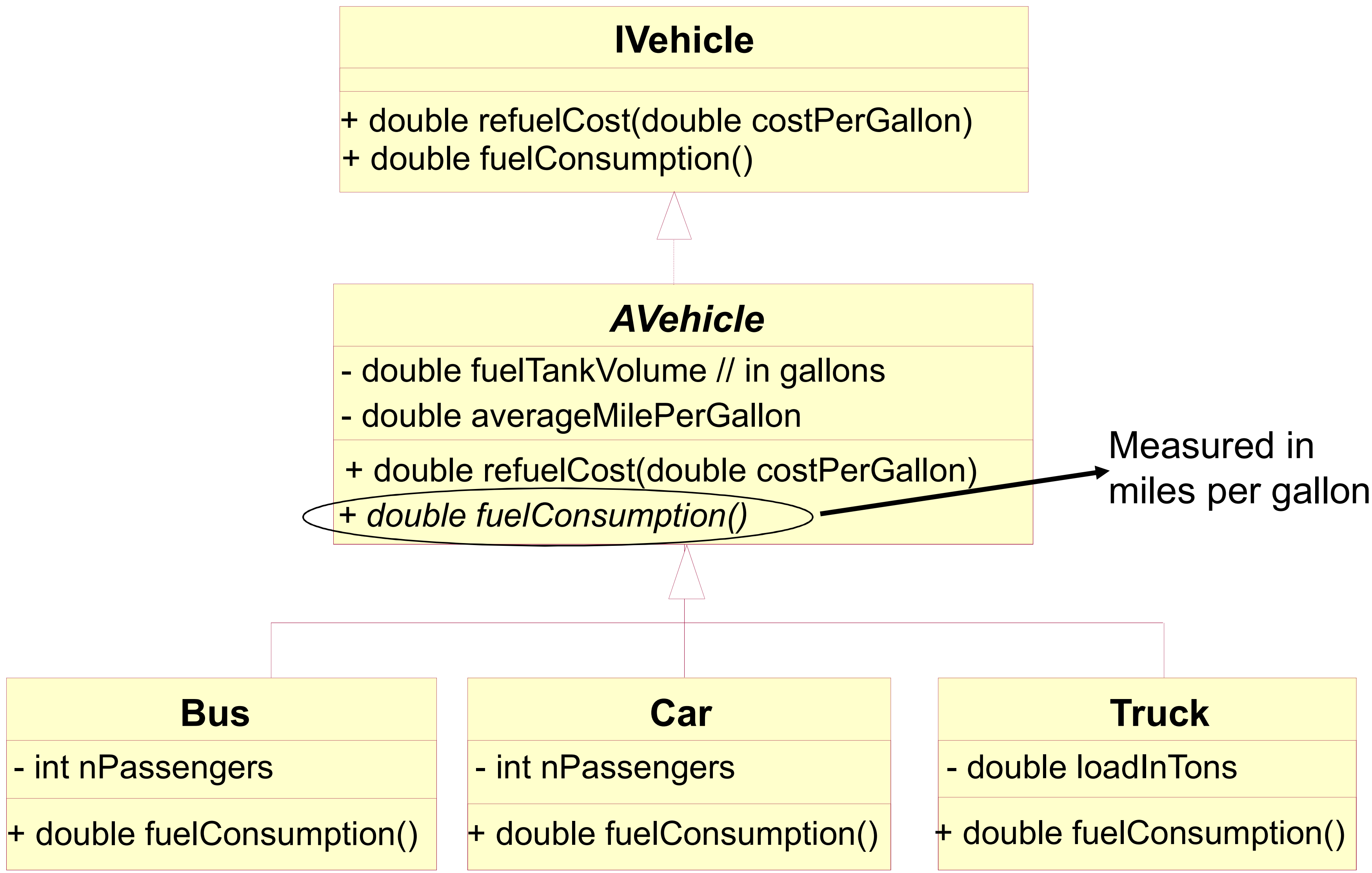
- In this case, all three methods are distinct from each other, and they must be defined for each specific concrete class of vehicles.

```
// inside Bus
public double fuelConsumption() {
   return this.averageMilePerGallon
         * (1 – 0.01*this.nPassengers);
}
```

```
// inside Car
public double fuelConsumption() {
   return this.averageMilePerGallon
            * (1 – 0.1*this.nPassengers);
}
```

```
// inside Truck
public double fuelConsumption() {
   return this.averageMilePerGallon
            * (1 – 0.05*this.loadInTons);
}
```

Improved Class Diagram



More Requirement

- Suppose the manager also wants to generate estimates about how far a vehicle can go, assuming it is freshly refueled.
  Design a method that can compute this estimate for each kind of vehicle.

howFar() in AVehicle

```
public interface IVehicle {
   public double refuelCost(double costPerGallon);
   public double fuelConsumption();
   // compute how far this vehicle can go
   public double howFar();
}
```

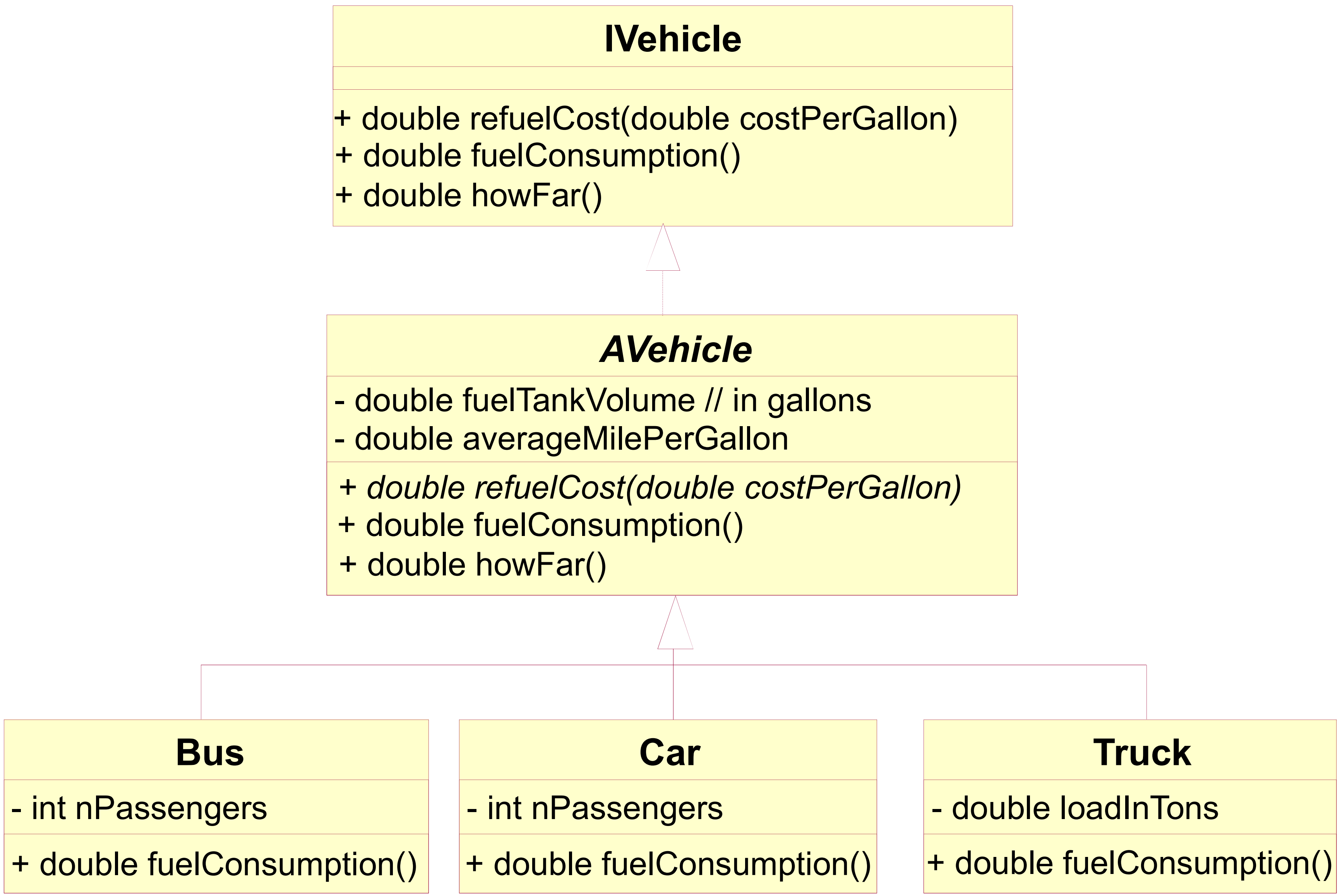
```
public abstract class AVehicle implements IVehicle {
   private double fuelTankVolume; // in gallons
   private double averageMilePerGallon;
   protected Avehicle(double fuelTankVolume,
            double averageMilePerGallon) {
      this.fuelTankVolume = fuelTankVolume;
      this.averageMilePerGallon = averageMilePerGallon;
   }
   public double refuelCost(double costPerGallon) {
      return costPerGallon * this.fuelTankVolume;
   }
   public abstract double fuelConsumption();
   public abstract double howFar();
}
```

`howFar()` implement

- Since three subclasses have the same implementation for `howFar()`, we could move this method to the parent class.
  This means `howFar()` now in the `AVehicle` class will not be abstract any more

```
public double howFar() {
   return this.fuelTankVolume * this.fuelConsumption();
}
```

Final Class Diagram



Exercise 4.1

Design a data representation for this problem:

. . . Develop a “bank account” program. The program keeps track of the balances in a person’s bank accounts. Each account has an id number and a customer’s name. There are three kinds of accounts: a checking account, a savings account, and a certificate of deposit (CD). Checking account information also includes the minimum balance. Savings account includes the interest rate. A CD specifies the interest rate and the maturity date. Naturally, all three types come with a current balance. . . .

- Represent the following examples using your classes:
  - Earl Gray, id# 1729, has $1,250 in a checking account with minimum balance of $500;
  - Ima Flatt, id# 4104, has $10,123 in a certificate of deposit whose interest rate is 4% and whose maturity date is June 1, 2005;
  - Annie Proulx, id# 2992, has $800 in a savings account; the account yields interest at the rate of 3.5%.

Exercise 4.2

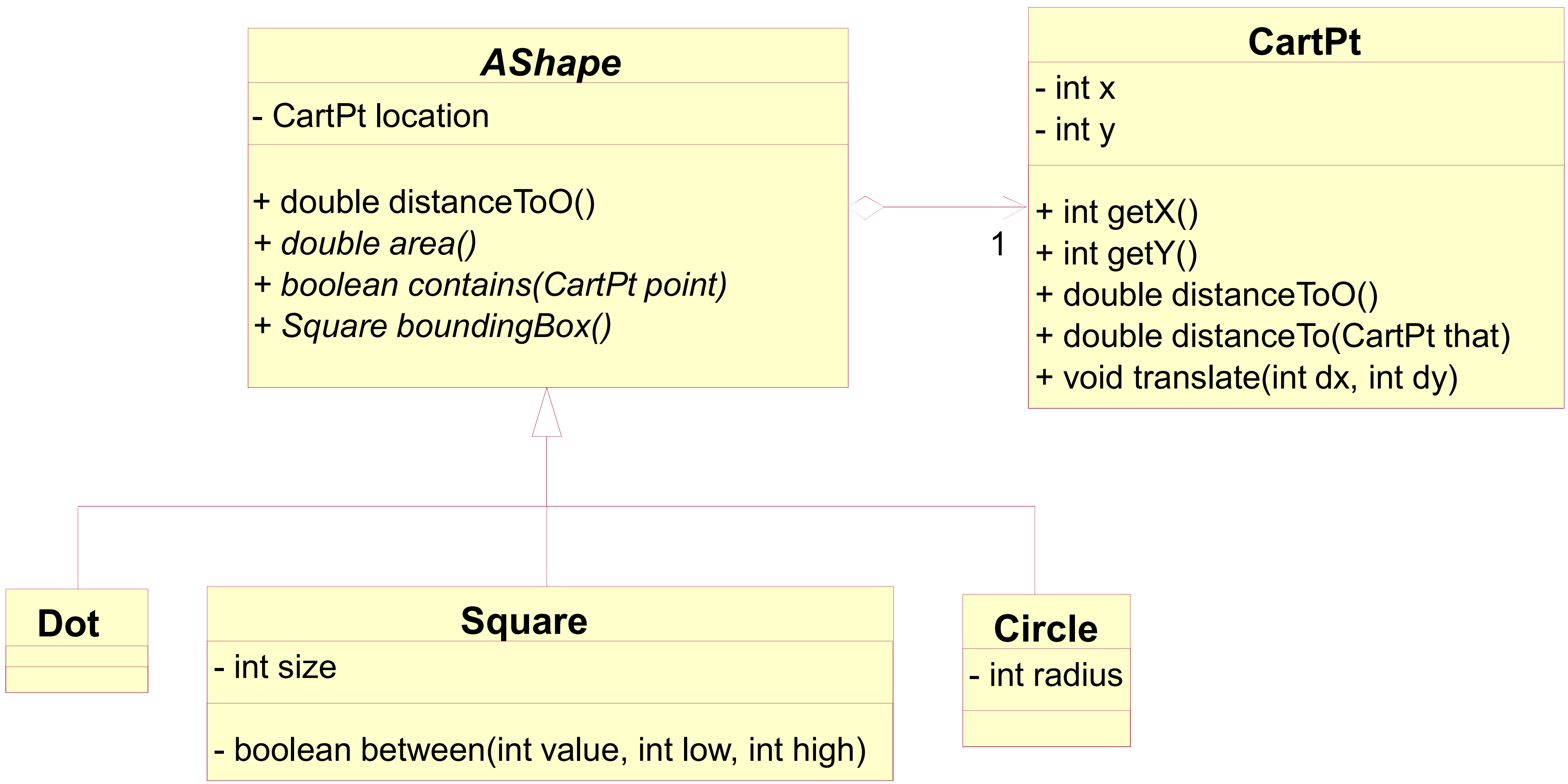
- Develop a program that creates a gallery from three different kinds of records: images (gif), texts (txt), and sounds (mp3). All have names for source files and sizes (number of bytes). Images also include information about the height, the width, and the quality of the image. Texts specify the number of lines needed for visual representation. Sounds include information about the playing time of the recording, given in seconds.
- Examples:
  - an image, stored in flower.gif; size: 57,234 bytes; width: 100 pixels; height: 50 pixels; quality: medium;
  - a text, stored in welcome.txt; size: 5,312 bytes; 830 lines;
  - a music piece, stored in theme.mp3; size: 40960 bytes, playing time 3 minutes and 20 seconds.

4.3 Extended exercises

- The administrators of metropolitan transportation agencies manage fleets of vehicles.
  Develop data definitions for a collection of such vehicles. The collection should include at least buses, limos, cars, and subways. Add at least two attributes per class of vehicle.

Exercise 4.4

- Class diagram for the classes in the shape hierarchy



Exercise 4.4 con't

4.4.1 Design an extension for the class hierarchy of shapes that deals with `Rectangles`.
The extension should cope with all the abstract methods in `AShape`

4.4.2 Design an extension for the class hierarchy of shapes so that a program can request the length of the perimeter for each shape in the hierarchy

4.4.3 Extended
Compute the bounding box the class hierarchy of shapes that deals with `Rectangles`. The extension should cope with all the abstract methods in `AShape`

Exercise 4.5

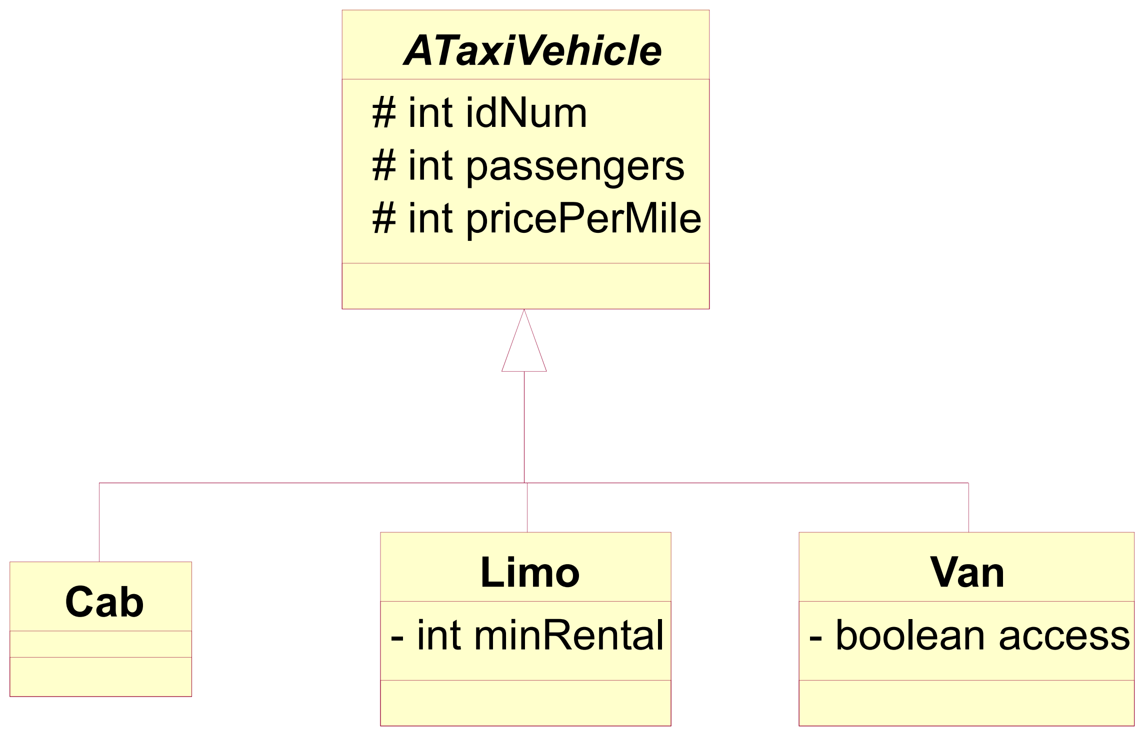
- Develop a program that creates a gallery from three different kinds of records: images (gif), texts (txt), and sounds (mp3). All have names for source files and sizes (number of bytes). Images also include information about the height, the width, and the quality of the image. Texts specify the number of lines needed for visual representation. Sounds include information about the playing time of the recording, given in seconds.
- Develop the following methods for this program:
  - **timeToDownload**, which computes how long it takes to download a file at some network connection speed, typically given in bytes per second;
  - **smallerThan**, which determines whether the file is smaller than some given maximum size that can be mailed as an attachment;
  - **sameName**, which determines whether the name of a file is the same as some given name.

Exercise 4.6

- Develop a program that keeps track of the items in the grocery store. For now, assume that the store deals only with ice cream, coffee, and juice. Each of the items is specified by its brand name, weight (gram) and price (cents). Each coffee is also labeled as either regular or decaffeinated. Juice items come in different flavors, and can be packaged as frozen, fresh, bottled, or canned. Each package of ice cream specifies its flavor and whether this is a sorbet, a frozen yogurt, or regular ice cream.
- Design the following methods:
  - **unitPrice**, which computes the unit price (cents per gram) of some grocery item;
  - **lowerPrice**, which determines whether the unit price of some grocery item is lower than some given amount;
  - **cheaperThan**, which determines whether a grocery item is cheaper than some other, given one in terms of the unit cost.

Exercise 4.7

- Recall the class hierarchies concerning taxi vehicles from exercise 4.3:



Exercise 4.7 (cont)

Add the following methods to the appropriate classes in the hierarchy:

- *fare*, which computes the fare for a vehicle, based on the number of miles traveled, and using the following formulas for different vehicles:
  - passengers in a cab just pay flat fee per mile
  - passengers in a limo must pay at least the minimum rental fee, otherwise they pay by the mile
  - passengers in a van pay $1.00 extra for each passenger
- *lowerPrice*, which determines whether the fare for a given number of miles is lower than some amount;
- *cheaperThan*, which determines whether the fare in one vehicle is lower than the fare in another vehicle for the same number of miles.

Exercise 4.8

- Develop a program that assists a bookstore manager in a discount bookstore. The program should keep a record for each book. The record must include its title, the author's name, its price, and its publication year. In addition, the books There are three kinds of books with different pricing policy. The hardcover books are sold at 20% off. The sale books are sold at 50% off. The paperbacks are sold at the list price. Here are your tasks:
- Develop a class hierarchy for representing books in the discount bookstore.
- Develop the following methods:
  - ***salePrice***, which computes the sale price of each book;
  - ***cheaperThan***, which determines whether a book is cheaper than another book;
  - ***sameAuthor***, which determines whether a book was written by some given author which wrote another book.