Object Oriented Programming

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Kyoung Shin Park
Computer Engineering
Dankook University

Software Crisis

- SW Crisis
  - The term "**software crisis**" was coined by Fridrich L. Bauer at the first NATO Software Engineering Conference in 1968.
  - The **causes** of the software crisis is related to
    - the **overall complexity of the software development process**
    - and the relatively **immaturity of software engineering**.
  - The crisis manifested itself in several ways
    - Projects running over-budget
    - Projects running over-time
    - Software was very inefficient
    - Software was of low quality
    - Software often did not meet requirements
    - Projects were unmanageable and code difficult to maintain
    - Software was never delivered

Software Quality

- Comparison with Architecture
  - Assuming you are building a house, how do you measure the quality?
  - What if one room came out less than you planned?
    - This is a significant design flaw.
  - Even if you made everything according to the design,
    - What if you can't meet the moving-in date?
    - What if the cost is more than your planned budget?
  - Design compliance is important, but delivery and cost are also important

Software Quality

- Software Quality
  - Quality problems fail to solve the set of requirements with the given amount of time with given amount of efforts
  - Time
    - Should not exceed the time limit
  - Effort
    - Measured in man-month
    - Same as time and cost
  - Requirements
    - Functions that the users want
    - Not what the developers want

Software Severity

- As software becomes larger, the crisis becomes more serious
  - Assuming a large enterprise program as 10,000,000 LOC
    - It's about 200,000 pages where 1 page contains 50 lines
    - It's about 700 books where 1 book contains 300 pages
  - The development cost is 300 billion won if 1 LOC costs 30,000 won
    - This cost including requirement analysis, design, testing, documentation, and inspection
- Problems in large-scale software development
  - Problems of collaboration
    - The importance of design
    - Divide, develop, and integrate large-scale software development
  - Problems of requirement
    - Requirements continue to grow

Software Severity

- The severity of the software error
  - There is a tendency not to value the severity of the software error
  - Software errors may threaten human life in medical and military fields
  - Software errors may cause financial losses in bank and financial sectors
  - Accident of 2016 Tesla autonomous driving

차량의 자동주행센서가 밝게 빛나는 하늘과
트럭의 흰색 면을 미처 구분하지 못한 것으로
테슬라 측은 파악하고 있다.

https://www.mk.co.kr/news/special-edition/view/2016/07/473465/

Good Software?

- User-centered design is a key concept in software development
  - Functionality, Efficiency, Maintainability, Reusability, Readability, etc are important
  - It is important to implement all the functions that users need, but it should be easy to maintain, easy to reuse, and easy to read
    - Maintenance costs will be increased if the software is not made easy to read
- Good Software
  - Easy to edit code because there is no code duplication and easy to understand
  - Convenient for others to take

Object-Oriented Programming

- Paradigm changes as a way to solve the SW crisis.
  - Changes towards faster and better to reduce software development time and cost → Paradigm shift to OOP
- Must understand the characteristics of object orientation
  - What is different compared to non-OOP?
    - Understanding what improves programming
  - Understanding inheritance as a way to reuse common parts
    - Distinguish when to use and when not to use

Object-Oriented Programming

- What is Object-oriented programming?
  - OOP is one of the programming styles
  - OOP improves the problems of procedural programming or structured programming
  - OOP consists of two elements (data and code)
    - Data
      - Value used for I/O and used while code is executed
    - Code
      - Commands run by the computer
      - Use data to solve problems and produce results

Procedural Programming

- Problems of procedural programming
  - Separate procedures and data
  - Example: Gasoline car
    - The **move()** expresses the process of moving a car. The fuel enters the car engine and burns it to move the car. The energy generated in this process is transferred to the wheels to move the car.
    - You only need to call the **move()** when moving the car.
    - The **move()** needs **data** called ***fuel***, but it cannot be put in the function.
      - The solution is passed as a parameter.

Problem with Procedural Programming

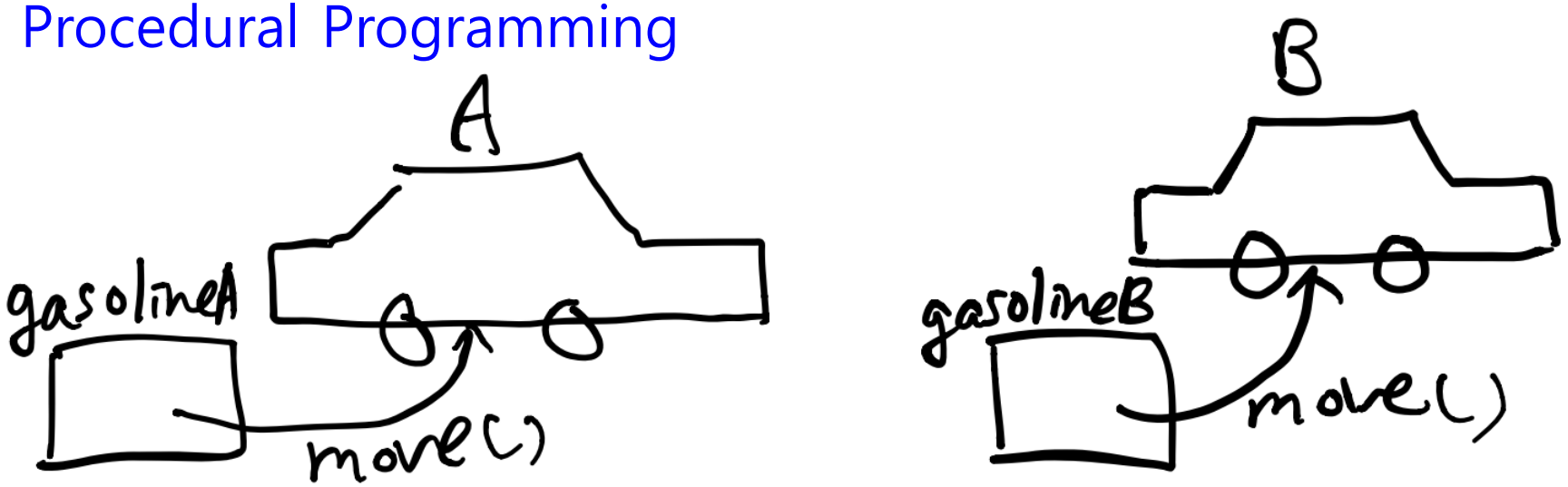
```
void move(Car car, double gas) {
    // Use the given gas
    // burn the gas in the engine
    // transmit power to the wheel
    // to move the car
    ...
}

double gasoline = 20.0;
move(A, gasoline);
```

Problem with Procedural Programming

- What if there are two cars?

```
double gasolineA = 20.0;
double gasolineB = 20.0;
move(A, gasolineA);
move(B, gasolineB);
```

Procedural Programming



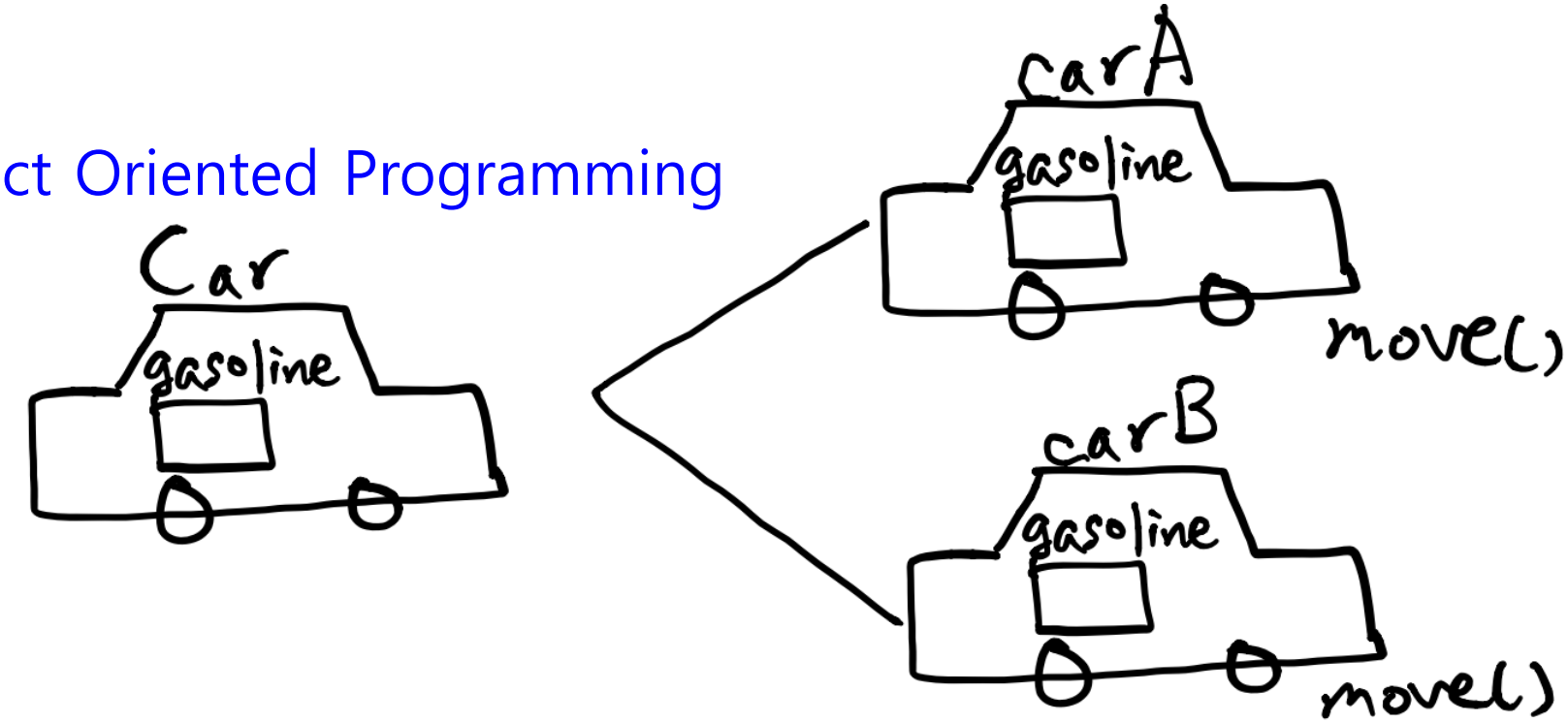
Object-Oriented Programming

- In object-oriented programming, data and procedures are grouped together using classes, and treated as a single data type.

```
class Car {
    double gasoline;
    void move() {
            …
     }
}
Car carA = new Car();
Car carB = new Car();
carA.move();
carB.move();
```

Object-Oriented Programming

Object Oriented Programming



- The advantage of OOP is the reusability and readability of code.

OOP Concepts

- Object – objects have states and behaviors
- Class – defines the grouping of data and code, the "type" of an object
- Instance – specific allocation of a class
- Abstraction – hide the internal implementation of the feature, and only show the functionality to the user
- Encapsulation – keep implementation private and separate from interface
- Inheritance – hierarchical organization, code reusability, customize or extend behaviors
- Polymorphism – process objects differently based on their data type, using same interface

Abstraction

- Abstraction
  - Hide the underlying complexity of data
  - Help avoid repetitive code
  - Present only the signature of internal functionality
  - Give flexibility to programmers to change the implementation of the abstract behavior
  - Partial abstraction (0~100%) can be achieved with abstract classes
  - Total abstraction (100%) can be achieved with interfaces

Encapsulation

- Encapsulation
  - Restrict direct access to data members (fields) of a class
  - **Fields** are set to **private**
  - Each field has a **getter** and **setter** method
  - Getter methods return the field
  - Setter methods let us change the value of the field

Inheritance

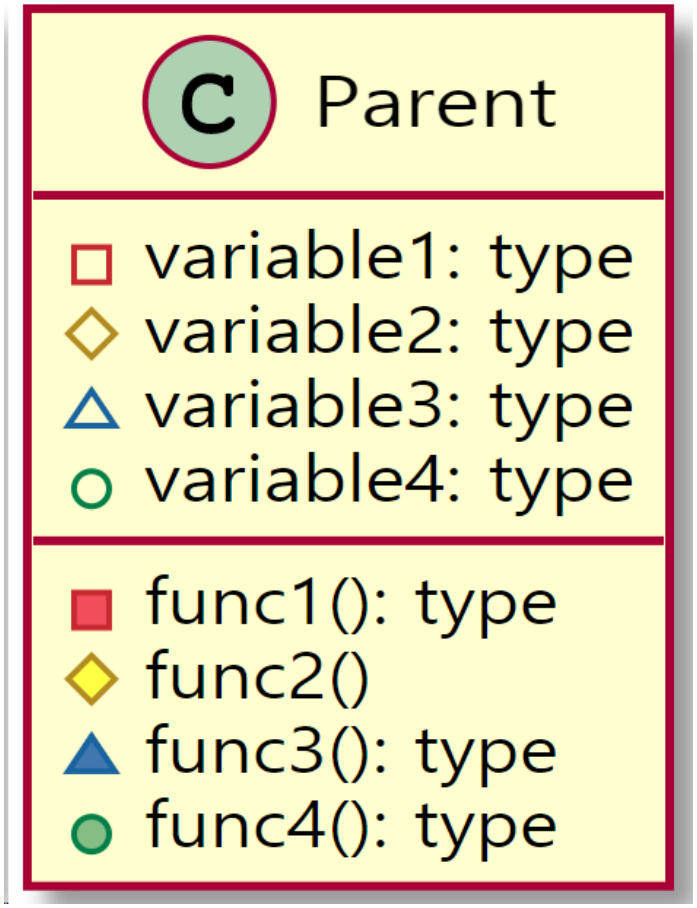
- Inheritance
  - A class (child class) can **extend** another class (parent class) by inheriting its features
  - Implement the DRY (Don't Repeat Yourself) programming principle
  - Improves **code reusability**
  - Multilevel inheritance is allowed in Java (a child class can have its own child class as well)
  - **Multiple inheritances are not allowed** in Java (a class can't extend more than one class)

Polymorphism

- Polymorphism
  - Polymorphism means existing in many forms
  - It means objects of different types can be accessed through the same interface. Each type can provide its own, independent implementation of this interface.
  - All Java objects can be considered polymorphic (at the minimum, they are of their own type and instances of the Object class)
  - Polymorphism could be static and dynamic.
  - Example of static polymorphism in Java is method overloading.
  - Example of dynamic polymorphism in Java is method overriding

UML Class Diagram

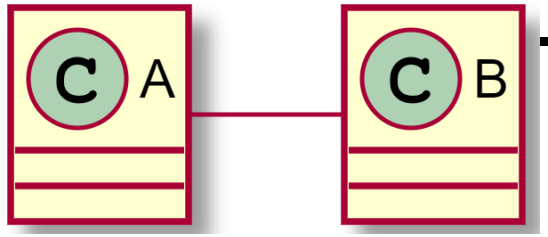
- Divide into three areas(class name, member fields, member methods)



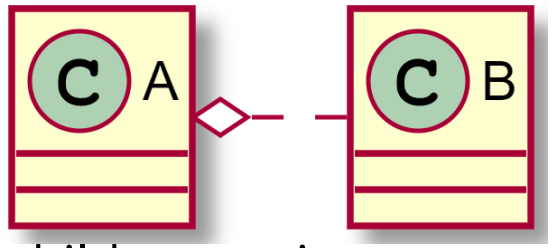
Character	Icon for field	Icon for method	Visibility
-	□	■	private
#	◇	◆	protected
~	△	▲	package private
+	○	●	public

UML Class Diagram

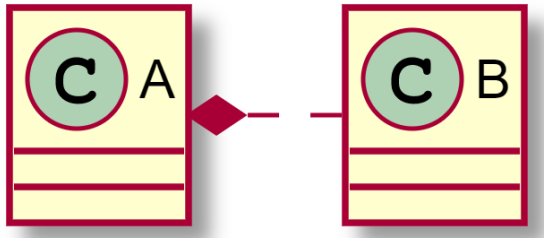
- Association
  - A and B class are associated with each other.
  - **Aggregation** and **Composition** are subsets of **Association**, i.e., specific cases of Association.



- Aggregation
  - Aggregation implies a relationship where the child can exist independently of the parent.



- Composition
  - Composition implies a relationship where the child cannot exist independent of the parent.
  - When A is deleted, then B is also deleted as a result.



UML Class Diagram

- Association

```
public class A { // A uses B
    void test(B b) { }
}
```

- Aggregation

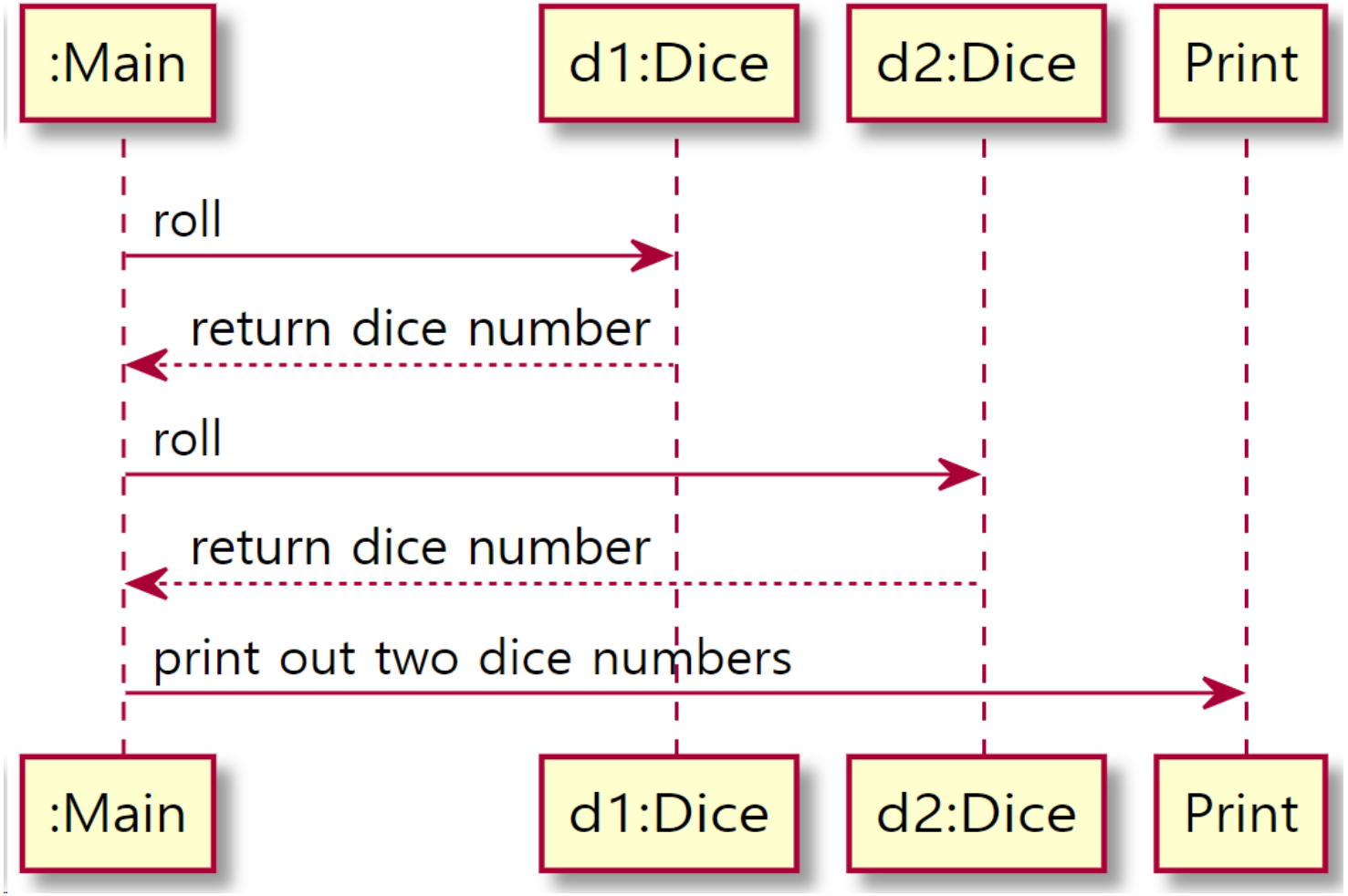
```
public class A { // When A dies, B may live on
    private B b;
    A(B b) { this.b = b; }
}
```

- Composition

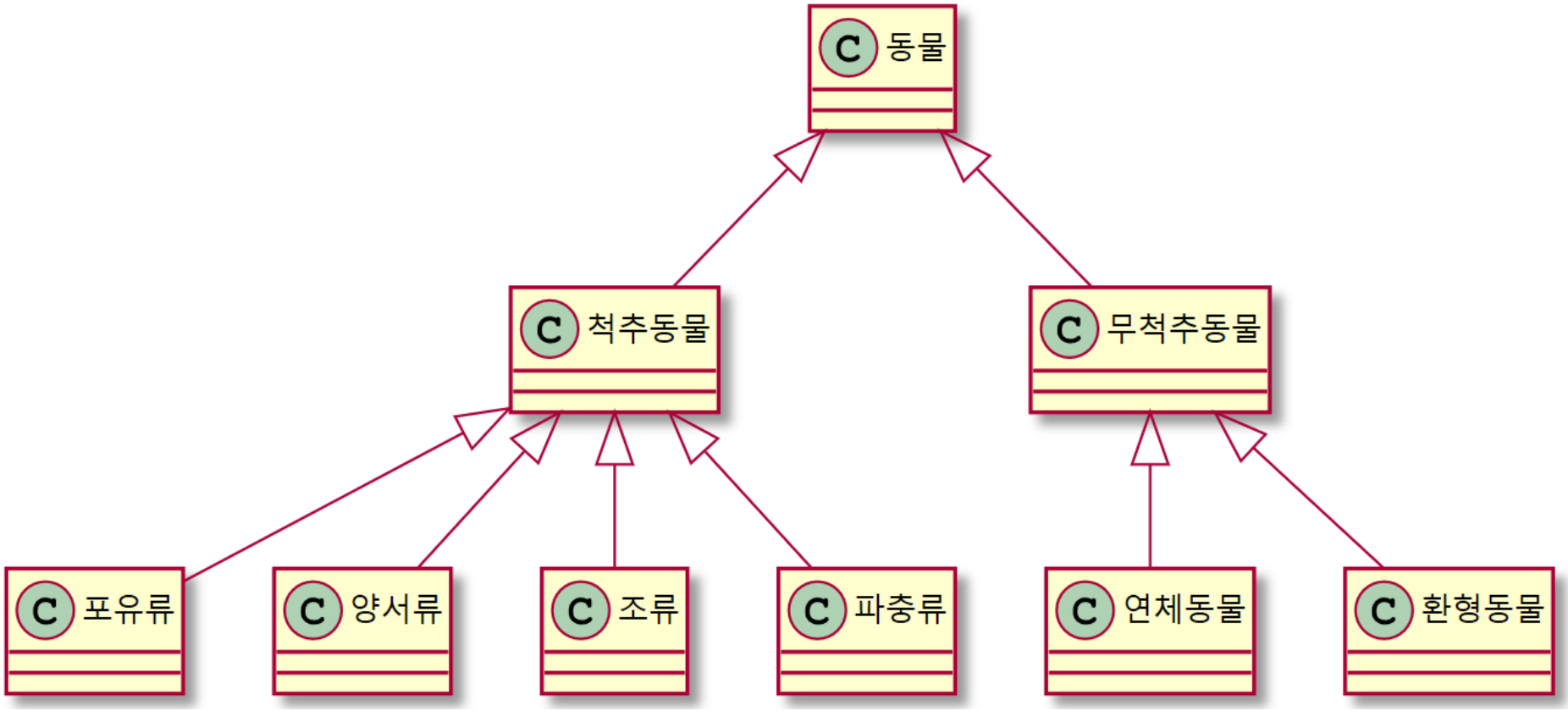
```
public class A { // When A dies, so does B
    private B b = new B();
}
```

UML Sequence Diagram

- Sequence Diagram – interaction diagram that details how operations are carried out (the order of the interaction)

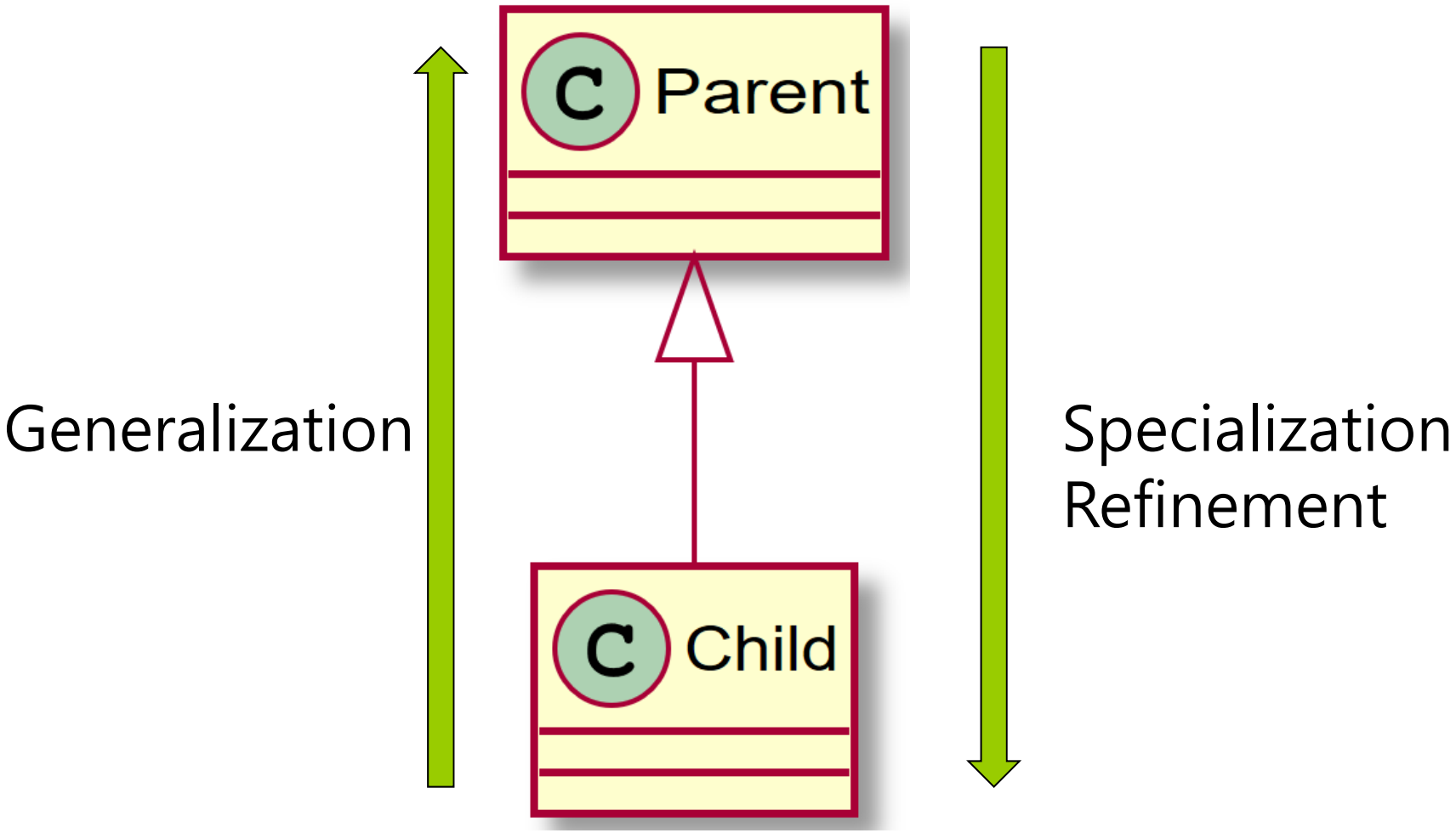


Inheritance



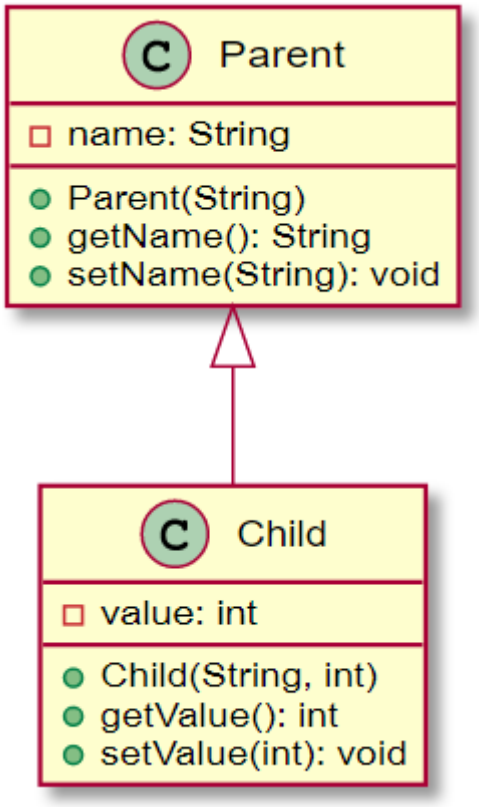
Inheritance

- Inheritance - extend, specialization



Inheritance

- A **constructor cannot** be **inherited** in Java.



Parent's memory

String name
Parent (String n)
String getName()
void setName(String n)

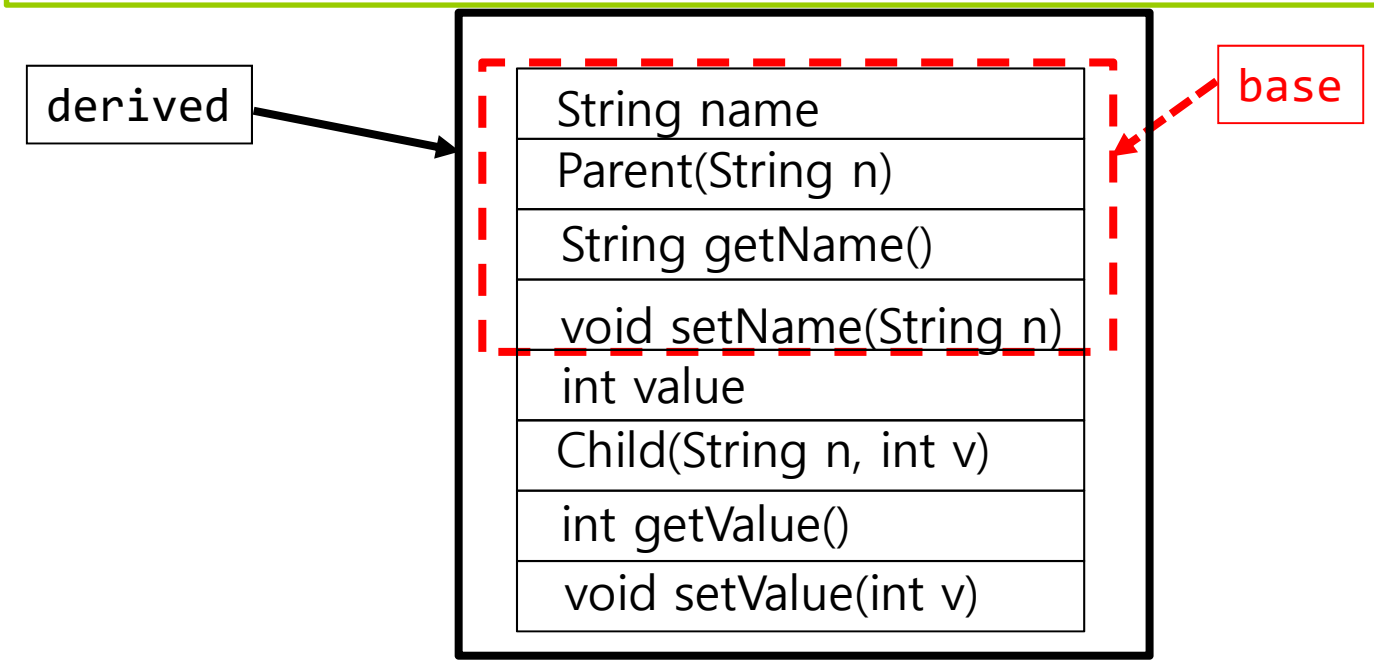
Child's memory

String name
Parent(String n)
String getName()
void setName(String n)
int value
Child(String n, int v)
int getValue()
void setValue(int v)

Inheritance

- You can store child object in parent reference (upcasting)
- Then, you can only access the parent members but it's not possible to access the child members.

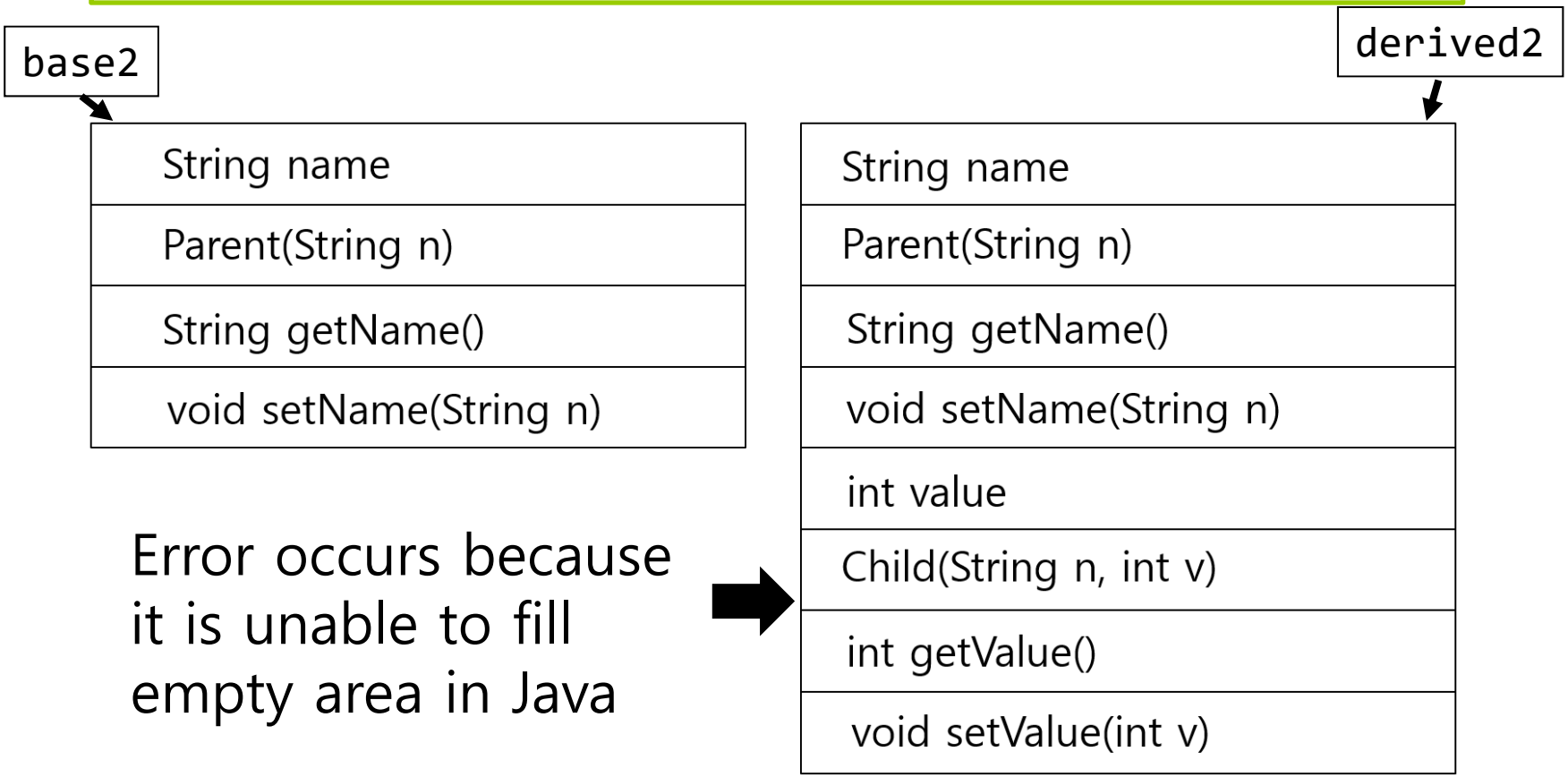
```
Parent base;
Child derived = new Child("park", 2020);
base = derived; // upcasting
```



Inheritance

- Downcasting **cannot** be done **implicitly**.

```
Parent base2 = derived;
Child derived2 = base2; // compile error
```



Inheritance

- Downcasting means **typecasting** of a parent object to a child object. However, the original object must be a child.

```
Child derived2 = (Child)base2; // downcasting
System.out.println(derived2.getValue());
Parent base3 = new Parent("park");
Child derived3 = (Child)base3; // error
```

- **instanceof**
  - If the left reference is the right class (or subclass) object, then it returns true, otherwise it returns false.
  - If there is an inheritance relationship, the child class object is also identified as an object of the parent class.

```
if (derived2 instanceof Child) // true
if (derived2 instanceof Child) // true
```

Method Overloading

- Method Overloading
  - Different number or types of function parameters
  - Return type is meaningless
  - Valid in the same class or classes with inheritance relationship

```
void print() { … } // method overloading
void print(String s) { … } // method
overloading
void print(int n) { … } // method overloading
void print(String s, int n) { … } // method
overloading
int print(int n) { … } // error
```

Method Overriding

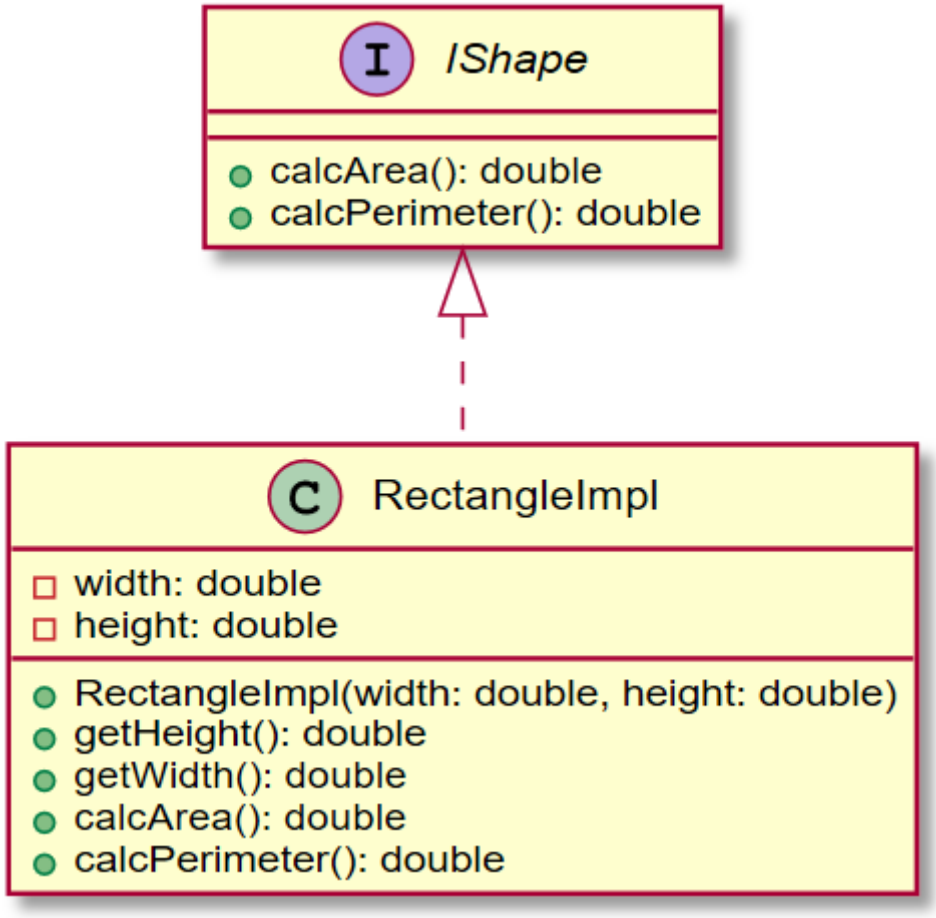
- Method Overriding
  - The function's signature is the same
  - Only meaningful in inheritance relationships

```
class Parent {
    void print() { … }
    void print(String s, int n) { … }
}
class Child extends Parent {
    void print() { xxx } // method overriding
    void print(String s, int n) { xxx } //
method overriding
}
```

Interface vs Abstract Class

- Interface
  - Can have constants and abstract methods (only the function signature of the class to be implemented)
  - From Java 8, it can have default and static methods (pre-implemented function)
  - Class implementing interface must implement those that have only function signature.
  - Members of a Java interface are public by default
- Abstract Class
  - Has one or more abstract methods (only the function signature)
  - Can have member fields
  - Can have abstract and non-abstract methods
  - Can have class members like private, protected, public, default

Interface


IShape
calcArea(): double
calcPerimeter(): double
RectangleImpl
width: double
height: double
RectangleImpl(width: double, height: double)
getHeight(): double
getWidth(): double
calcArea(): double
calcPerimeter(): double

Interface

```
// IShape.java
interface IShape {
    double calcArea();
    double calcPerimeter();
}
// RectangleImpl.java
class RectangleImpl implements IShape {
    private double width, height;
    public RectangleImpl(double width,
                         double height) {
        this.width = width;
        this.height = height;
    }
```

Interface

```
    @Override
    public double calcArea() {
        return width * height;
    }
    @Override
    public double calcPerimeter() {
        return 2 * (width + height);
    }
    public double getHeight() { return height; }
    public double getWidth() { return width; }
}
```

Interface

```
// RectangleMain.java
class RectangleMain {
    public static void main(String[] args) {
        IShape r = new RectangleImpl(10., 20.);
        System.out.println(r.calcArea());
    }
}
```

Interface – default method

```
//IValue.java
interface IValue {
    default int getValue() { return 0; }
}
// ValueImpl1.java
class ValueImpl1 implements IValue {
    private String name = "ValueImpl1";
    ValueImpl(String s) { name = s; }
    public String getName() { return name; }
    public void setName(String s) {
        name = s;
    }
}
```

Interface – default method

```
// ValueImpl2.java
class ValueImpl2 implements IValue {
    private String name;
    ValueImpl2() {
        name = "ValueImpl2";
    }
    public String getName() { return name; }
    public void setName(String s) {
        name = s;
    }
    public int getValue() { return 1; } // default
method overriding
}
```

Interface – default method

```
// ValueMain.java
class ValueMain {
    public static void main(String[] args) {
        ValueImpl1 v1 = new ValueImpl1("ValueImpl1");
        ValueImpl2 v2 = new ValueImpl2();
        System.out.println(v1.getName());
        System.out.println(v2.getName());
        IValue i1 = v1;
        IValue i2 = v2;
        System.out.println(i1.getValue()); // 0
        System.out.println(i2.getValue()); // 1
    }
}
```

Abstract Class

```
// Shape.java
abstract class Shape {
    public abstract double calcArea();
    public abstract double calcPerimeter();
}
// RectangleImpl.java
class Rectangle extends Shape {
    private double width, height;
    public Rectangle(double width, double height) {
        this.width = width;
        this.height = height;
    }
```

Abstract Class

```
    @Override
    public double calcArea() {
        return width * height;
    }
    @Override
    public double calcPerimeter() {
        return 2 * (width + height);
    }
    public double getHeight() { return height; }
    public double getWidth() { return width; }
}
```

Abstract Class

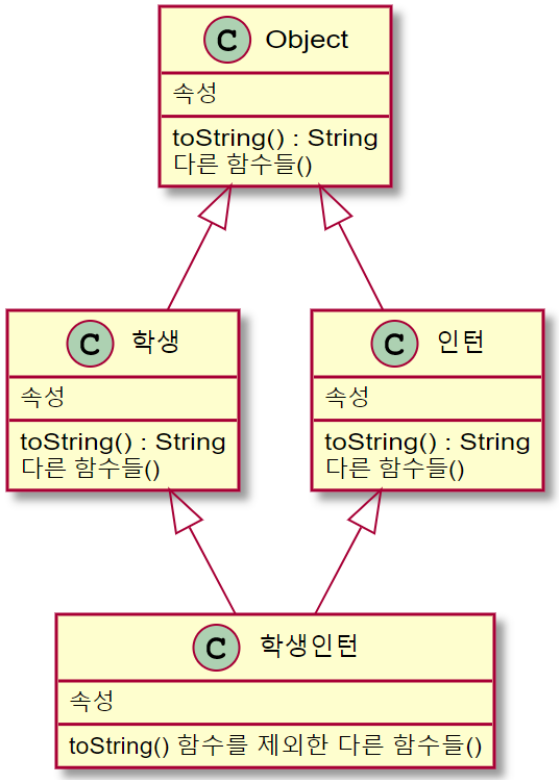
```
public class Circle extends Shape {
    private double radius;
    public Circle(double radius) {
        this.radius = radius;
    }
    @Override
    public double calcArea() {
        return Math.PI * radius * radius;
    }
    @Override
    public double calcPerimeter() {
        return 2 * Math.PI * radius;
    }
    public double getRadius() { return radius; }
}
```

Abstract Class

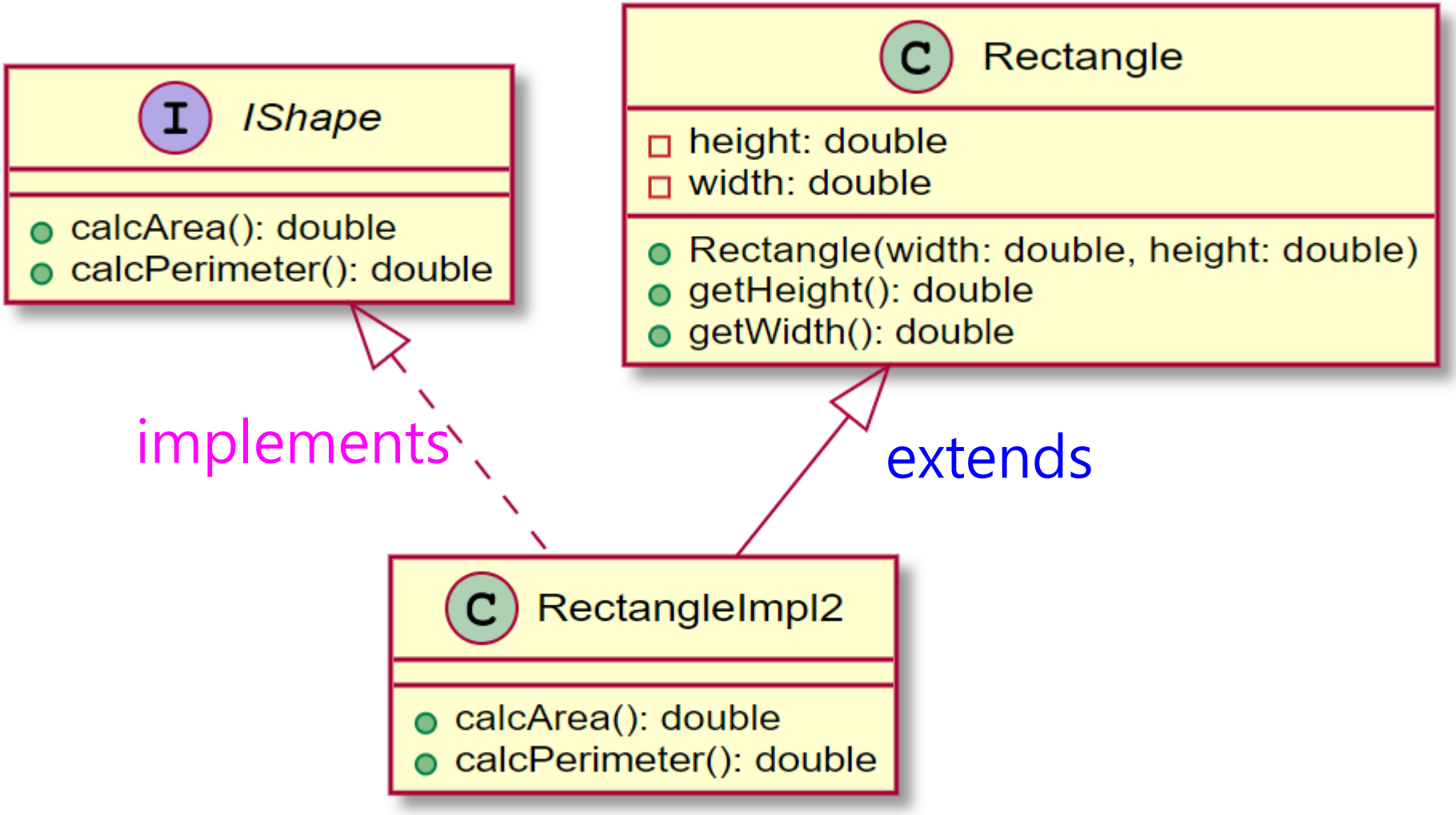
```
// AbstractShapeMain.java
class AbstractShapeMain {
    public static void main(String[] args) {
        Shape r = new Rectangle(20.0, 10.0);
        Shape c = new Circle(10);
        System.out.printf("Rectangle area:
%.2f\n", r.calcArea()); // dynamic binding
        System.out.printf("Circle perimeter:
%.2f\n", c.calcPerimeter()); // dynamic binding
    }
}
```

Multiple Inheritance

- The "**diamond problem**" is an ambiguity that can arise as a consequence of allowing multiple inheritance.
- Java does not allow multiple inheritance.
- Use interfaces instead of classes to achieve the same purpose



Multiple Inheritance



Multiple Inheritance

```
interface IShape {
    double calcArea();
    double calcPerimeter();
}
class Rectangle {
    private double width, height;
    public Rectangle(double width, double height) {
        this.width = width;
        this.height = height;
    }
    public double getHeight() { return height;  }
    public double getWidth() { return width;  }
}
```

```
// RectangleImpl2.java
class RectangleImpl2 extends Rectangle
                     implements IShape {
    public RectangleImpl2(double width,
                          double height) {
        super(width, height);
    }
    @Override
    public double calcArea() {
         return getWidth() * getHeight();
    }
    @Override
    public double calcPerimeter() {
        return 2 * (getWidth() + getHeight());
    }
}
```

Multiple Inheritance

```
// RectangleMain.java
class RectangleMain {
    public static void main(String[] args) {
        RectangleImpl2 r = new RectangleImpl2(10, 10);
        Rectangle r2 = r;
        System.out.println(r2.getHeight());
        IShape s = r;
        System.out.println(s.calcArea());
    }
}
```

Multiple Inheritance – Interface default method

```
interface IValue {
    default int getValue() { return 0; }
}
class ValueImpl {
    private String name = "ValueImpl";
    ValueImpl() { }
    ValueImpl(String s) { name = s; }
    public String getName() { return name; }
    public void setName(String s) {
        name = s;
    }
}
```

Multiple Inheritance – Interface default method

```
// ValueImpl1.java
class ValueImpl1 extends ValueImpl implements IValue {
    ValueImpl1(String s) {
        super(s);
    }
}
// ValueImpl2.java
class ValueImpl2 extends ValueImpl implements IValue {
    ValueImpl2() {
        super();
        setName("ValueImpl2");
    }
    public int getValue() { return 1; } // default
method overriding
}
```

Multiple Inheritance – Interface default method

```
// ValueMain.java
class ValueMain {
    public static void main(String[] args) {
        ValueImpl1 v1 = new ValueImpl1("ValueImpl1");
        ValueImpl2 v2 = new ValueImpl2();
        System.out.println(v1.getName());
        System.out.println(v2.getName());
        IValue i1 = v1;
        IValue i2 = v2;
        System.out.println(i1.getValue()); // 0
        System.out.println(i2.getValue()); // 1
    }
}
```

Polymorphism

- Polymorphism
  - Allow us to perform a single action in different ways
  - Execute specialized actions based on its type
  - Call overridden methods in child classes from the parent reference variable at run time (dynamic binding)

```
public class ShapeTag {
   private String tag;
   public ShapeTag(String tag) {
       this.tag = tag;
   }
   public String toString() { return "#" + tag; }
}
```

```
public class RectangleTag extends ShapeTag {
    private String rectangleTag;
    public RectangleTag(String tag,
                        String rectangleTag) {
        super(tag);
        this.rectangleTag = rectangleTag;
    }
    @Override // Object toString method overriding
    public String toString() {
        return "#" + rectangleTag + " "
                + super.toString();
    }
    public String getRectangleTag() {
        return rectangleTag;
    }
}
```

```
public class CircleTag extends ShapeTag {
    private String circleTag;
    public CircleTag(String tag,
                     String circleTag) {
        super(tag);
        this.circleTag = circleTag;
    }
    @Override // Object toString method overriding
    public String toString() {
        return "#" + circleTag + " "
               + super.toString();
    }
    public String getCircleTag() {
        return circleTag;
    }
}
```

Polymorphism

```
ShapeTag s1 = new ShapeTag("shape1");
ShapeTag s2 = new ShapeTag("shape2");
RectangleTag r =
        new RectangleTag("shape", "rectangle");
CircleTag c = new CircleTag("shape", "circle");
System.out.println("Shape1 Tag: " + s1);
System.out.println("Shape1 Tag: " + s2);
System.out.println("Rectangle Tags: " + r);
System.out.println("Circle Tags: " + c);
```

```
Shape1 Tag: #shape1
Shape2 Tag: #shape2
Rectangle Tags: #rectangle #shape
Circle Tags: #circle #shape
```

Polymorphism

```
s1 = r; // upcasting
s2 = c; // upcasting

System.out.println("Rectangle Tags: " + s1); //
dynamic binding
System.out.println("Circle Tags: " + s2); //
dynamic binding
```

```
Rectangle Tags: #rectangle #shape
Circle Tags: #circle #shape
```

Polymorphism

```
ArrayList list = new ArrayList();
list.add(new ShapeTag("shape1"));
list.add(new ShapeTag("shape2"));
list.add(new RectangleTag("shape", "rectangle"));
list.add(new CircleTag("shape", "circle"));
for (Object o : list) {
    System.out.println(o); // dynamic binding
}
```

calcArea() using Polymorphism

- The area calculation method differs depending on the type of Shape.
- Comparison between non-OOP and OOP polymorphism
  - Version 1 – Use instanceof to classify the class object, and then call the calcArea()
  - Version 2 – Use polymorphism

```
Rectangle r = new Rectangle(3, 4);
Circle c = new Circle(5);
Shape[] shapes = new Shape[2];
shapes[0] = r;
shapes[1] = c;
```

calcArea() using Polymorphism

- Version 1: Use instanceof

```
for (Shape shape : shapes) {
    if (shape instanceof Rectangle) {
        Rectangle r = (Rectangle) shape;
        System.out.println(r.calcArea());
    }
    else if (shape instanceof Circle) {
        Circle c = (Circle) shape;
        System.out.println(c.calcArea());
    }
}
```

calcArea() using Polymorphism

- What if a new class called Triangle is added?

```
for (Shape shape : shapes) {
    if (shape instanceof Rectangle) {
        Rectangle r = (Rectangle) shape;
        System.out.println(shape.calcArea());
    }
    else if (shape instanceof Circle) {
        Circle c = (Circle) shape;
        System.out.println(c.calcArea());
    }
    else if (shape instanceof Triangle) {
        Triangle t = (Triangle) shape;
        System.out.println(t.calcArea());
    }
}
```

calcArea() using Polymorphism

- Version 2 – Use polymorphism

```
for (Shape shape : shapes)
    System.out.println(shape.calcArea());
```

- What if a new class called Triangle is added?

Generics

- ArrayList
  - Data structure that allows access to elements using index, similar to array
  - ArrayList is dynamic in size.
  - ArrayList cannot contains primitive data types, and it can only contains objects
  - You can insert elements into the ArrayList using add() method
  - Length of the ArrayList is provided by the size() method

```
ArrayList list = new ArrayList();
list.add("Seoul");
list.add(new String("Tokyo"));
list.add(new Integer(3));
list.add(5); // auto-boxing
```

Generics

- Problem with non-generic ArrayList
  - Can store any type of object
  - Need typecasting (downcasting) when using the object
  - Need to remember which element is which datatype is
  - Mainly used for one data type

```
String s1 = list.get(0); // compile error – need typecasting
String s2 = (String) list.get(1);
String s3 = (String) list.get(2); // runtime exception
Integer i1 = (Integer) list.get(2);
int i2 = (Integer) list.get(3);
```

Generics

- Generics make errors to appear compile time than at run time.

```
ArrayList<String> list = new ArrayList<>();
list.add("Seoul");
list.add(new String("Tokyo"));
list.add(new Integer(3)); // compile error
String s = list.get(0); // no need for type casting
```

Generics

- Create a generic MyArrayList

```
class MyArrayList<E> {
    ArrayList list;
    public MyArrayList() {
        list = new ArrayList();
    }
    public void add(E e) {
        list.add(e);
    }
    public E get(int i) {
        return (E) list.get(i);
    }
}
```

Generics

```
MyArrayList<String> l = new MyArrayList<>();
l.add("temp");
l.add("add");
String s = l.get(0);
```