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Objects, UML, and Java

Slides originally by Ken Wong

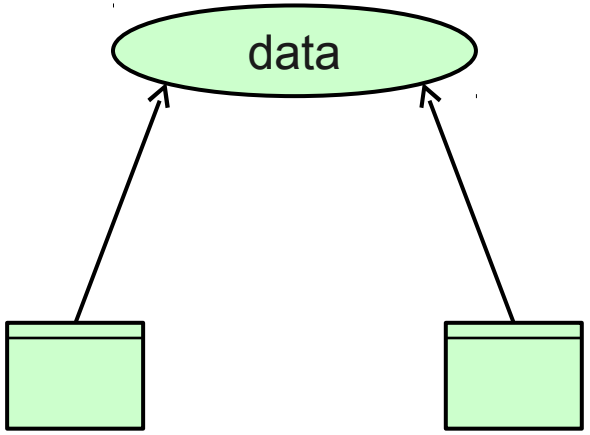
Modeling Principles

Language Evolution

COBOL, Fortran:

subprograms (subroutines)
access global data

break up system
into subroutines



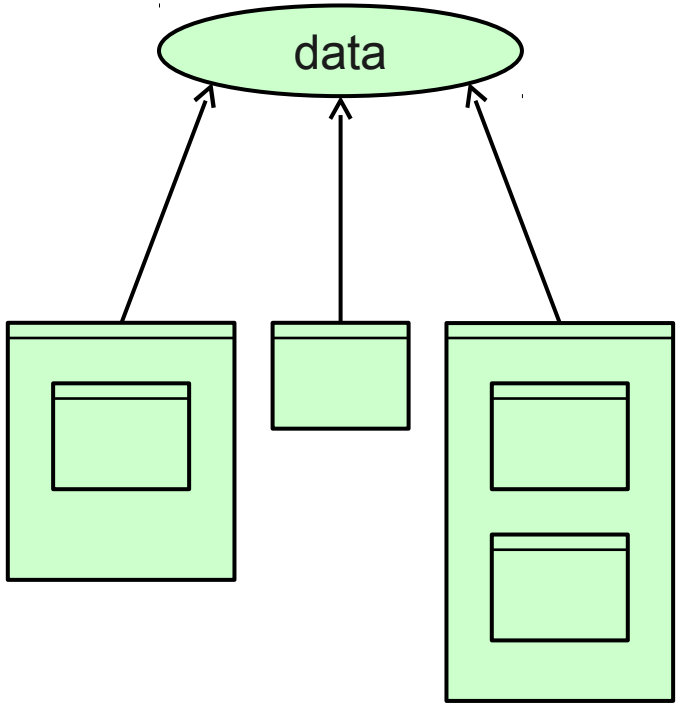
subprograms

Language Evolution

Algol, Pascal:

(nested) procedures with block structured scope

break up system into nested procedures

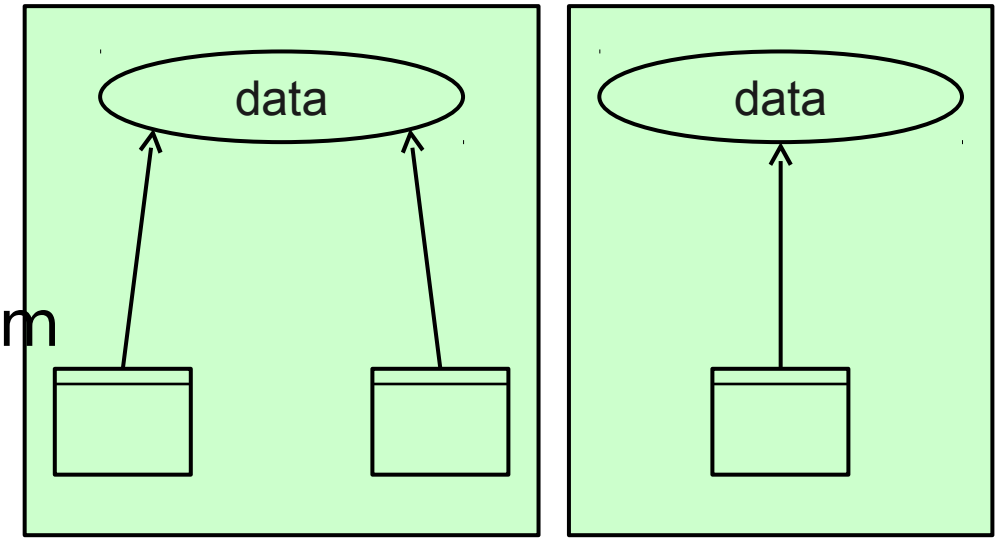


nested procedures

Language Evolution

Modula-2, C:

- modules (files) of related data and functions
- break up system into modules (e.g., abstract data types)



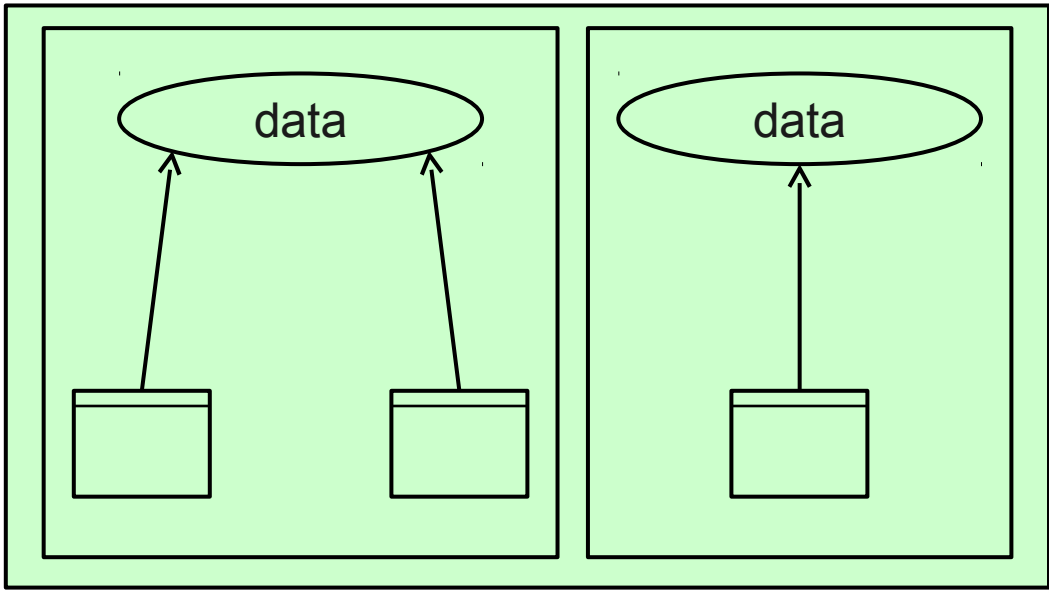
modules

Language Evolution

Smalltalk, C++, Java:

classes with data and methods

classes as “factories” for objects



classes

break up system into classes

Discussion

Question:

What software engineering design principles drove this evolution?

Abstraction

Simplifying to its essentials the description of a real-world entity or concept

coping with complexity

“selective ignorance”

modeling the problem space

e.g., a “Person” abstraction

Encapsulation

Bundling data with access functions

distinguishing “what” from “how”

“need to know” restricted access

maintaining integrity

information hiding criterion

- hide changeable internal details from the outside world, but reveal assumptions through interface

e.g., a “Person” abstract data type

Decomposition

Dividing whole things into parts
or composing whole things out of parts

“separation of concerns”

data parts

- fixed or dynamic number
- sharing of parts
- life time of parts

Generalization

From specific cases, looking for commonalities that can be factored out

- reusing common designs
- reducing redundant code
- making systems flexible and extensible

Object-Oriented Models

Object-Oriented Models

Implementing OO models:
OO programming languages

- e.g., Java, C++

Expressing OO models:
OO design notations

- e.g., UML

Java

Principal designer:

James Gosling, Sun Microsystems

Language goals:

simple, object-oriented

robust, secure

network and thread support

“compile once, run anywhere”

Java

Language design inspired by ...

Lisp	garbage collection, reflection
Simula-67, C++	classes
Algol-68	overloading
Pascal, Modula-2	strong type checking
C	syntax
Ada	exceptions
Objective C, Eiffel	interfaces
Modula-3	threads

Unified Modeling Language (UML)

Principal inventors:

Grady Booch, Ivar Jacobson, James Rumbaugh

Purpose:

express object-oriented designs visually

programming language independent

communicate, evaluate, and reuse designs

make design intent more explicit

can think about design, before coding

Abstraction

Object:

an entity with specific attribute values (state), behavior, and identity

typically instantiated from a class

Class:

associated type of an object

defines attributes and methods

Java and UML Class

```
public class Frame { // version 0
    // represent a ‘window’
    /* body of class definition goes here */
}
```

UML class notation

Encapsulation

Class:

access control for attributes and methods

- e.g., public or private

access is not the same as visibility

“design by contract”

- public interface represents a contract between the developer who implements the class and the developer who uses the class

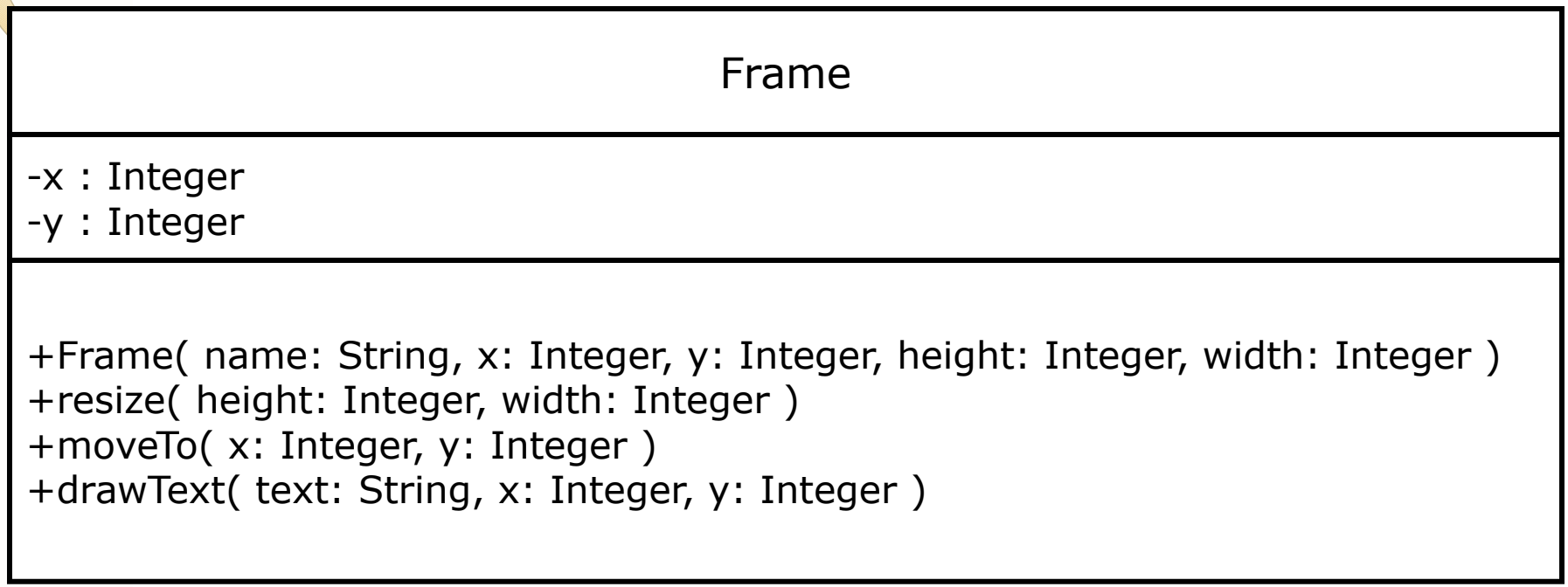
Java Class

```
public class Frame { // version 1
    // private implementation

    private datatype variablename;

    // public interface

    public Frame( arguments ) {
        // implementation of constructor
    }

    public returntype methodname( arguments ) {
        // implementation of method
    }
}
```

Java Class

```
public class Frame { // version 2
    private int x;
    private int y;
    …
    public Frame ( String name,
        int x, int y, int height, int width ) { … }

    public void resize(
        int newHeight, int newWidth ) { … }

    public void moveTo(
        int newX, int newY ) { … }

    public void drawText( String text,
        int x, int y ) { … }
}
```

UML Class



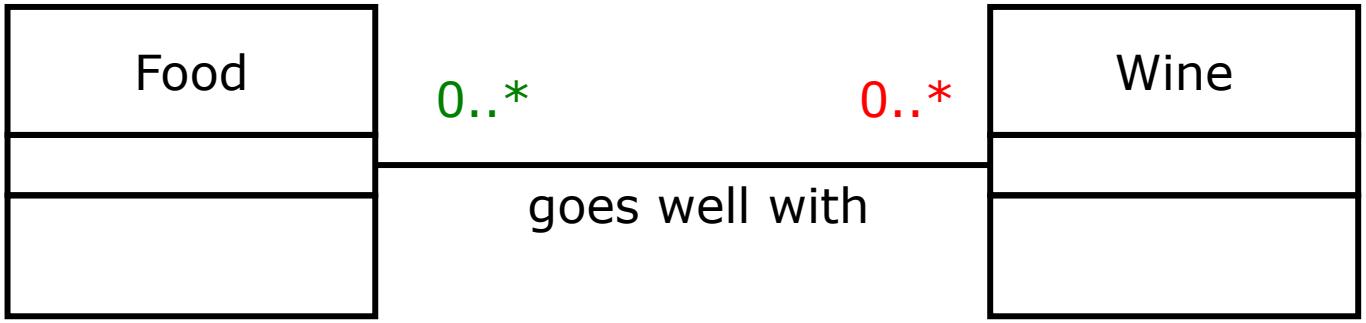
– private
+ public

Decomposition

Association relationship:
“some” relationship between classes

- e.g., between Book and Patron

UML Association



Read class diagram using “objects”

a Food *object* goes well with a Wine *object*

a Food *object* is associated with
0 or more Wine *objects*

a Wine *object* is associated with
0 or more Food *objects*

Decomposition

Aggregation relationship:

weak “has-a” relationship

whole “has-a” part

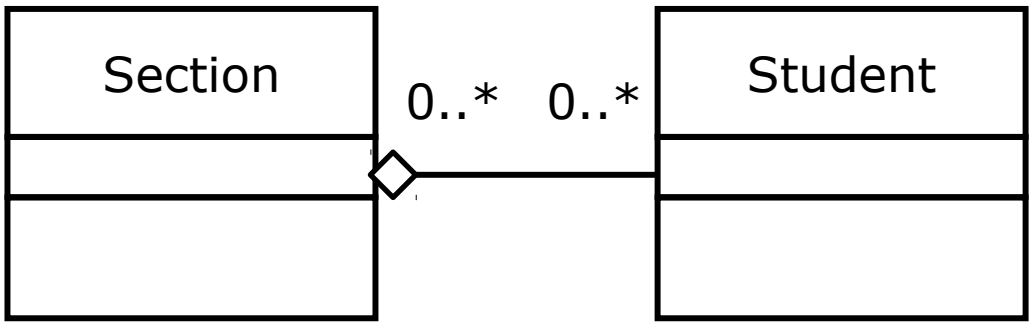
a part may belong to (be shared with) other wholes

e.g., a Section and a Student

Java and UML Aggregation

Dynamic number of aggregated objects:

```
public class Section {
    private ArrayList<Student> roster;
    …

    public Section() {
        roster = new ArrayList<Student>();
        …
    }
    public void add( Student s ) { … }
}
```



Java and UML Aggregation

Fixed number of aggregated objects:

```
public class Frame {

    private Location myLocation; // shared object
    private Size mySize; // shared object
    …
}
```

Decomposition

Composition relationship:

strong “has-a” relationship

exclusive containment of parts

related object life times

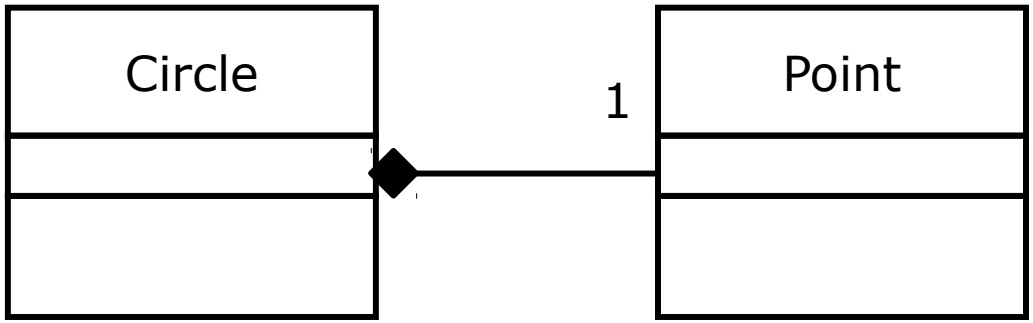
- the whole cannot exist without having the parts; if the whole is destroyed, the parts should also be destroyed

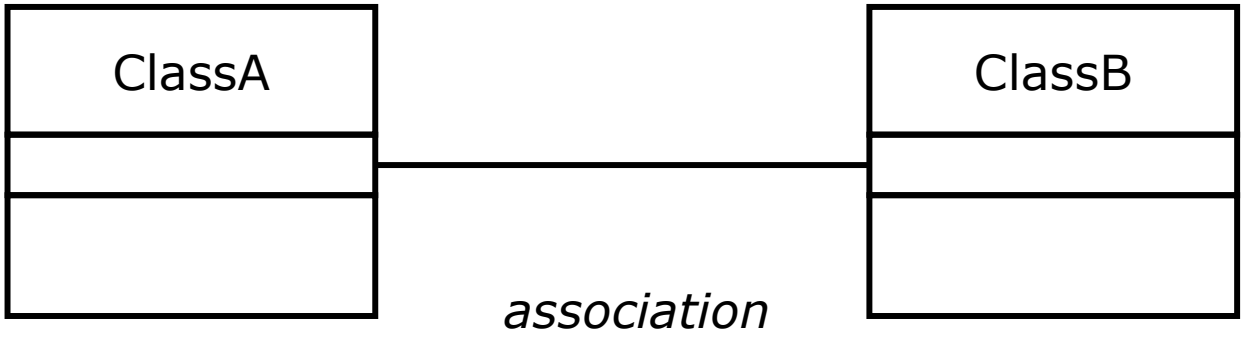
often access the parts through the whole

UML Composition

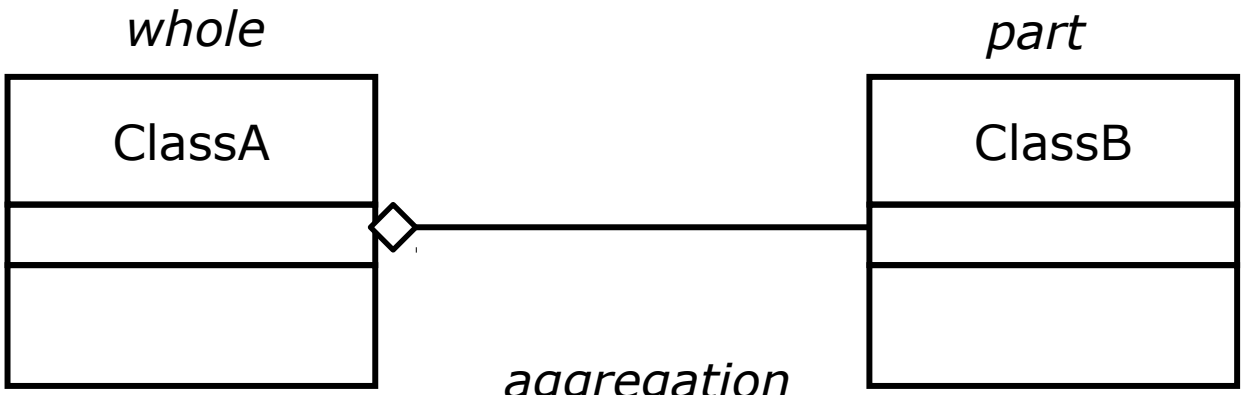
Contained *objects* are exclusive to the container

a Circle object has a Point object that is exclusive to it (however, other objects may contain Point objects, just not this one)

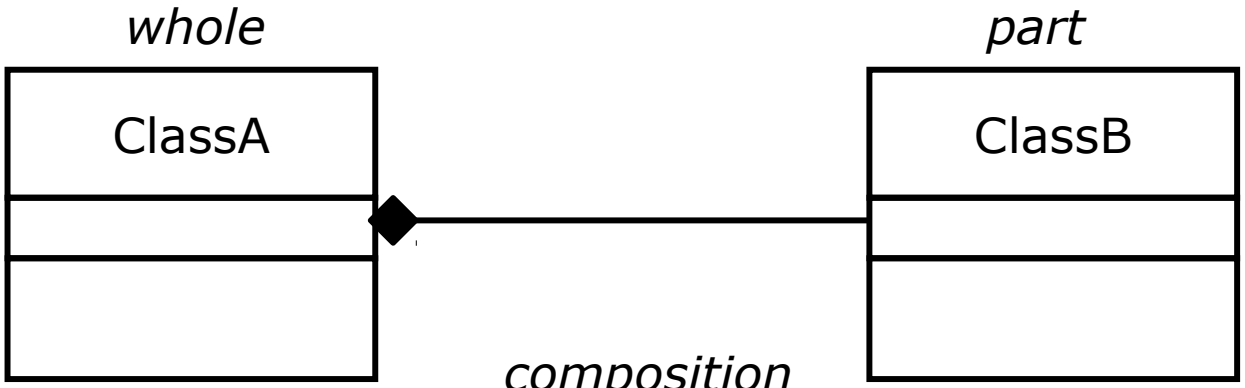




association



aggregation



composition

Exercise

Analyze a UML class model for a car rental company that keeps track of cars, renters, and renters renting cars.

Generalization

Generalization

Look for commonalities:

common attributes

- e.g., all vehicles have ?

common methods (behavior)

- e.g., all vehicles can ?

Generalize:

find what is common, and factor it out into a more general "base" abstraction

Generalization

Implementation inheritance:

generalize about method signatures, method implementations, and/or attributes

- i.e., classes having these in common

Implementation Inheritance

General part:

a base class (or “superclass”) defines the attributes and methods to be shared

Specific part:

a derived class (or “subclass”) is endowed with the attributes and methods of its base class

a subclass may “extend” a superclass by adding attributes and methods, or overriding an existing method

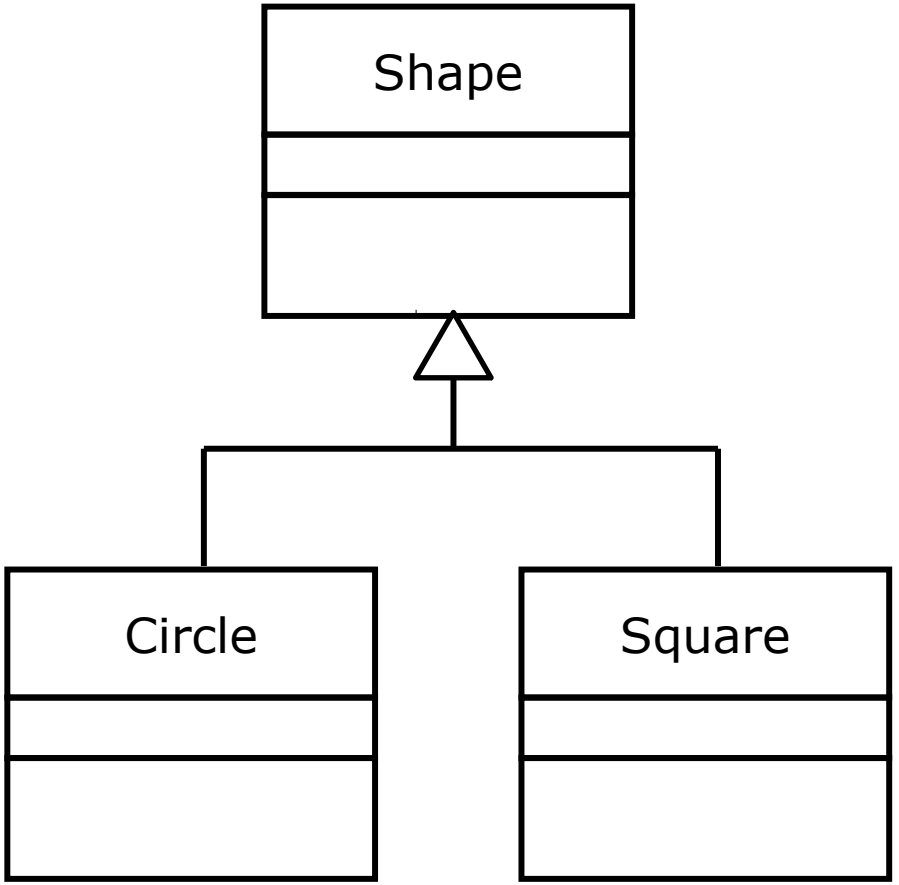
Java Implementation Inheritance

```
public class Shape { // superclass
    protected Location myLocation;
    public Shape() { … }
    public void setLocation( Location p ) { … }
    public Location getLocation() { … }
}

public class Circle extends Shape { // subclass
    private int diameter;
    public Circle() { … }
    public void setDiameter( int d ) { … }
    …
}
public class Square extends Shape { // subclass
    private int side;
    public Square() { … }
    public void setSide( int s ) { … }
}
```

UML Inheritance

Implementation inheritance relationship:

- "is-a" relationship between classes
- i.e., subclass "is-a" kind of superclass
- i.e., subclass "extends" superclass
- e.g., Circle "is-a" kind of Shape



Generalization Principles

Inappropriate inheritance:

subclass inherits from superclass but “is-a” (is a kind of) relationship *does not* exist

if “is-a” test fails

- likely not appropriate

if “is-a” test succeeds

- *may* or *may not* be appropriate

Generalization Principles

Liskov substitution principle:

an instance of the subclass should be substitutable anywhere a reference to a superclass object is used

```
Shape s;
s = new Circle(); // instance of subclass
…
Location l = s.getLocation(); // superclass method
```

Inheritance Example

Suppose:

class Dog

- provides bark(), fetch()

class Cat extends Dog

- “hides” bark(), “hides” fetch(), and adds purr()

Question:

Cat “is a” Dog?

Inheritance Example

Suppose:

class Window

- provides show(), move(), resize()

class FixedSizeWindow extends Window

- “hides” resize()

Question:

FixedSizeWindow “is a” Window?

Inheritance Example

Suppose:

class ArrayList

- provides add(), get(), remove(), …

class ProjectTeam extends ArrayList

Question:

ProjectTeam “is a” ArrayList?

Inheritance Issue

Problem:

superclass method is inherited, but it is not appropriate

what to do?

Inheritance Issue

```
public class Rectangle {
    public Rectangle( Size s ) { … }
    public void setLocation( Location p ) { … }
    public void setSize( Size s ) { … }
    public void draw() { … }
    public void clear() { … }
    public void rotate() { … }
}

public class Square extends Rectangle {

    // inherits setSize(), but want to “hide” it
}
// Square ‘is a’ Rectangle?
// Square specializes Rectangle?
```

Override the Method Approach

```
public class Square extends Rectangle {

    public void setSize( Size s ) {
        // should not implement
    }

}
```

Aggregation Approach

```
public class Square {
    private Rectangle rect;
    // Square 'has a' Rectangle,
    // not 'is a' Rectangle

    public Square( int side ) {
        rect = new Rectangle(
            new Size( side, side ) );
    }
    …
    public void setSide( int newSide ) {
        rect.setSize(
            new Size( newSide, newSide ) );
    }

    public void draw() {
        rect.draw();
    }
    …
}
```

Restructuring Approach

```
public class Quadrilateral {
    …
    public Quadrilateral() { … }
    public void setLocation( Location p ) { … }
    public void draw() { … }
    public void clear() { … }
    public void rotate() { … }
}

public class Rectangle extends Quadrilateral {
    public Rectangle( Size s ) { … }
    public void setSize( Size s ) { … }
}

public class Square extends Quadrilateral {
    public Square( int side ) { … }
    public void setSide( int side ) { … }
}
```

Inheritance

Java abstract class:

declares one or more abstract methods

cannot be instantiated; must be subclassed and have abstract methods overridden

```
public abstract class Shape {
    public abstract double area();
    public abstract double perimeter();
    // there may be other instance data and methods
}
class Circle extends Shape {
    public double area() { … }
    public double perimeter() { … }
}
```

Interface Inheritance

Java interface:

declares method signatures

classes implement the interface by providing all the method bodies

```
public interface Bordered {
    public double area();
    public double perimeter();
}
class Circle implements Bordered {
    public double area() { … }
    public double perimeter() { … }
}
```

Interface Inheritance

Java interface:

a “contract”, specifying a *capability* that an implementing classes must provide

gives method signatures, but no implementation

cannot be instantiated

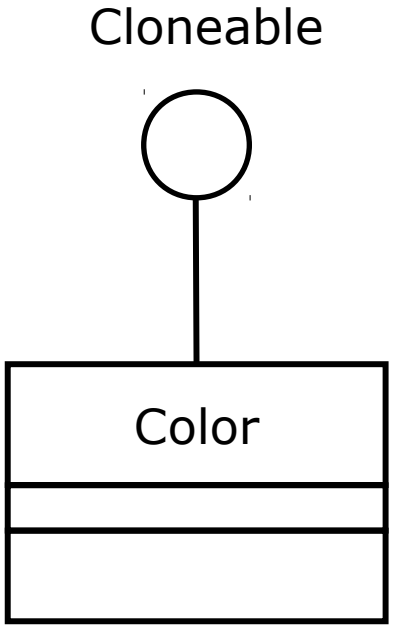
may extend other (sub)interfaces

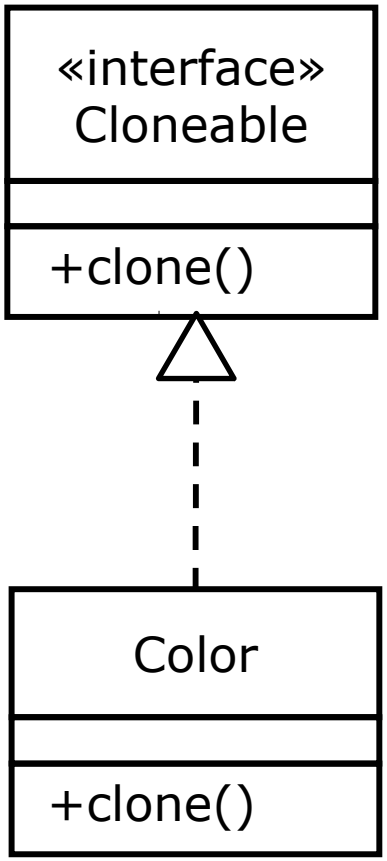
```
public interface Transformable extends Scalable,
Translatable, Rotatable {
    …
}
```

Java Interface

```
public interface Cloneable {
    public Cloneable clone();
}

public class Color implements Cloneable {
    private int red;
    private int green;
    private int blue;

    public Color( int r, int g, int b ) { … }

    public Cloneable clone() {
        return new Color( red, green, blue );
    }
}

Color red = new Color( 255, 0, 0 );
Color redClone = red.clone();
```

UML Interface





guillemets denote a stereotype

Abstract Class versus Interface

Differences:

- an abstract class may provide a partial implementation
- a class may implement any number of interfaces, but only extend one superclass
- adding a method to an interface will “break” any class that previously implemented it

Java Subtleties

Java Call-by-Value

```
public class Sender {
    public void send() {
        Receiver r = new Receiver();
        Info argRef = new Info();

        r.receive( argRef );
        argRef.doSomeMore();
    }
}

public class Receiver {
    public void receive( Info infoRef ) {
        infoRef.doSomething();
        infoRef = null;
    }
}
```

Java Constructors

```
public class Base {
    protected int value;
    public Base() {

        value = -1;
    }
}

public class Derived extends Base {
    public Derived() {

    }
}

Derived d = new Derived();
```

Java Constructors

```
public class Base {
    protected int value;
    public Base() {
        // implicitly inserted call to super()
        value = -1;
    }
}

public class Derived extends Base {
    public Derived() {
        // implicitly inserted call to super()
    }
}

Derived d = new Derived();
```

Java Constructors

```
public class Base {
    protected int value;
    public Base( int initValue ) {
        // implicitly inserted call to super()
        value = initValue;
    }
}

public class Derived extends Base {
    public Derived( int initValue ) {
        super( initValue );
        // explicit call to super( … );
        // super( … ) if used, must come first
    }
}

Derived d = new Derived( -1 );
```

Java Constructors

```
public class Base {
    protected int value;
    public Base( int initValue ) {
        // implicitly inserted call to super()
        value = initValue;
    }
    public Base() {
        this( -1 );
        // this( … ) if used, must come first
    }
}
public class Derived extends Base {
    public Derived( int initValue ) {
        super( initValue );
    }
    public Derived() {
        // implicitly inserted call to super()
    }
}
Derived d = new Derived();
```

Java Shadowing Data

```
public class Base {
    protected int value; // 2, 3
}

public class Derived extends Base {
    private int value; // 0, 1

    public void test() {
        value = 0;
        this.value = 1;
        super.value = 2;
        ((Base)this).value = 3;
    }
}
```

Java Dynamic Binding

selection of method to be run is made at run time, depending on type of receiving object

```
public class Base {
    // default implementation
    public void op() { … }
}
public class Derived1 extends Base {
    // does not override op()
}
public class Derived2 extends Base {
    // override ...
    public void op() { … }
}
```

receiving object does the "right thing", even if the calling code does not show its actual type

```
Base base;
base = new Derived1();  // implicit upcast
base.op();              // calls op() in Base
base = new Derived2();  // implicit upcast
base.op();              // calls op() in Derived2
```

Java Dynamic Binding

Upcast:

"widening" cast is safe due to the principle of substitutability

```
Base base = new Derived2(); // implicit upcast
base.op(); // calls op() in Derived2
```

Downcast:

"narrowing" cast must be explicit

```
Base base = new Derived2(); // implicit upcast
Derived2 derived = (Derived2)base; // downcast
derived.op(); // calls op() in Derived2
```

Overriding is not Shadowing

```
public class Base {
    public int i = 1;
    public int f() { return i; }
}
public class Derived extends Base {
    public int i = 2;                  // shadowing
    public int f() { return -i; }      // overriding
}
public class Test {
    public static void main( String args[] ) {
        Derived d = new Derived();
        // d.i is 2
        // d.f() returns -2
        Base b = (Base)d;
        // b.i is 1
        // b.f() returns -2, ‘dynamic binding’
    }
}
```

Object Oriented Analysis and Design

UML and OOA&D

Analysis:

requirements specification activity

- create UML use cases and class diagrams

Design:

architectural design activity

- refine UML class diagrams

detailed design activity

- refine UML class diagrams
- create UML sequence and state diagrams

Object-Oriented Analysis

Steps:

discover objects from problem domain

- nouns may lead to classes and attributes
- verbs may lead to relationships and methods

use CRC cards to note the analysis

evaluate

Problem Description

The library has books and magazines. Books may be borrowed by any patron for four weeks while magazines may only be borrowed for two days. Up to 6 items at a time may be borrowed. The system tracks when books and magazines are borrowed …

Nouns

The library has books and magazines. Books may be borrowed by any patron for four weeks while magazines may only be borrowed for two days. Up to 6 items at a time may be borrowed. The system tracks when books and magazines are borrowed …

Verbs

The library has books and magazines. Books may be borrowed by any patron for four weeks while magazines may only be borrowed for two days. Up to 6 items at a time may be borrowed. The system tracks when books and magazines are borrowed …

Discover Objects

Entity objects:
things that model the problem domain

Control objects:
things that respond to events and coordinate services

Boundary objects:
things that interact with the system

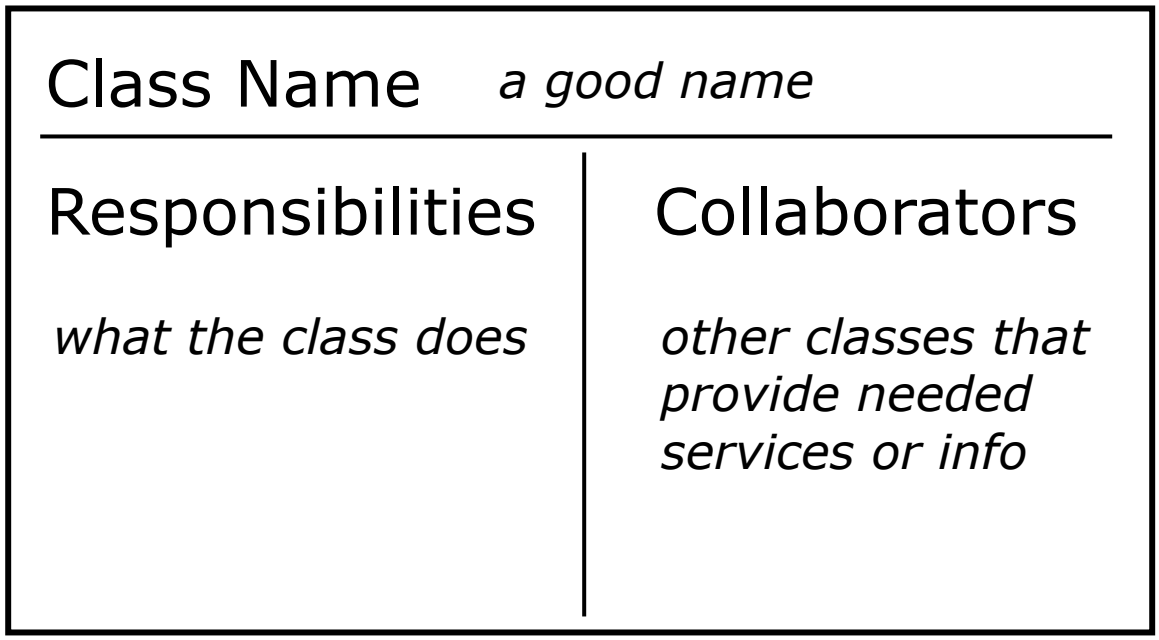
- e.g., other applications, devices, sensors, actors, roles, windows, forms

Use CRC Cards

Class-Responsibility-Collaborator

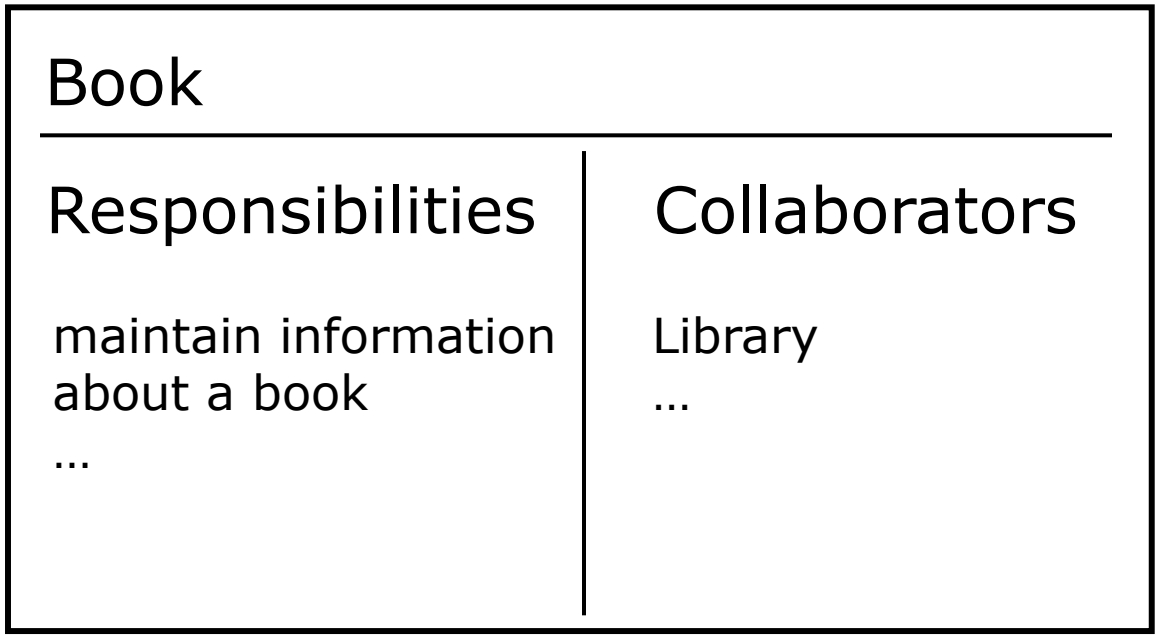
explore classes, their responsibilities, their interactions

organize index cards on a table



use the back for more details

Use CRC Cards



Use CRC Cards

Role playing:

refine the cards by acting out a particular scenario with the candidate objects

“become” the object

what do I do?

what do I need to remember?

with whom do I need to interact?

how do I respond?

Evaluate

Principles:

during analysis, objects should initially be technology independent

if an object has only one attribute, perhaps it should not be a separate object at all

if an object has several highly related attributes, perhaps these attributes should form a separate object

Guidelines

Get the big picture:

understand the problem

- talk to the customer, end users, domain experts

understand the target environment

- know the implementation constraints

avoid reinventing the wheel

- reuse designs

Guidelines

Modularity:

increase cohesion

- class has a clear specific responsibility

reduce coupling

- class is not connected to or knows too many others

separate the layers

- identify entity, control, and boundary objects
- allow replacing layers

Guidelines

Classes:

use good names

- should be meaningful and explanatory

avoid huge “blob” classes

- a single class can’t do everything

use information hiding

- hide changeable details, reveal assumptions

Guidelines

Generalization:

find superclasses

- look for and factor commonalities among classes

apply Liskov principle for proper inheritance

- or use is-a test

is-a test is not always enough

- class names can mislead, look at specific behavior

Guidelines

Adaptation:

hard to get it right the first time

- recognize problems and fix them

your software won’t go away

- make it easy to adapt to change

simplicity (as simple as possible)

- does not always mean using the first thing that comes to mind
- elegant designs may need effort

More Information

Books:

The Essence of Object-Oriented Programming with Java and UML

- B. Wampler
- Addison-Wesley, 2002

Java in a Nutshell

- D. Flanagan
- O'Reilly, 2005

More Information

Books:

UML Distilled

- M. Fowler
- Addison-Wesley, 2003

The Elements of UML 2.0 Style

- S. W. Ambler
- Cambridge, 2005

More Information

Link:

UML Quick Reference

- http://www.holub.com/goodies/uml/