Object Oriented Programming and Design in Java

Session 12

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Announcements

- Midterm exam Wednesday, Mar. 10^{th}
- Midterm sample problems and solutions posted on courseworks

Review

- Java Types
  - Arrays, enums
- The Object Class
  - toString(), equals(), clone(), hashCode()
- Hash tables

Today's Plan

- Design tools (UML, CRC cards, etc)
- Designing classes, programming by contract
- Interfaces and polymorphism
- Programming patterns
- Inheritance and hierarchy
- Types in Java

Ideas to Programs

Analysis (common sense)

↓

Design (object-oriented)

↓

Implementation (actual programming)

Use Cases

- Use cases specifically describe the operation of the program
- Narrows down exactly what you want your program to do
- Useful as test cases
- Implementation and design don’t matter

Identifying Classes

- Good first step: look for **tangible nouns** in use cases. Then...
- **Agents** - objects that perform tasks
- **Events** - store information about events
- **Systems, interfaces** - run the program, talk to user or other programs
- **Foundational classes** - String, Date, etc.

Identifying Responsibilities

- Good first step: look for verbs, actions in use cases
- These actions may directly describe responsibilities, or
- may depend on other responsibilities

CRC “Cards”

- Class - Responsibility - Collaborators
- Brainstorming tool for setting up classes and responsibilities
- Collaborators loosely define class relationships; we get more precise later

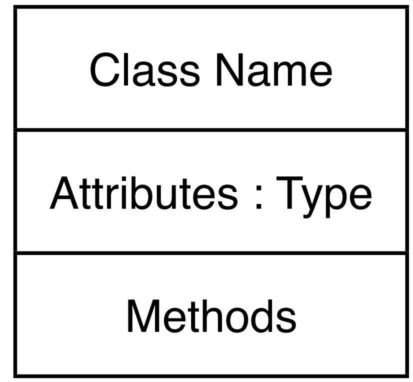
ClassName	
responsibility 1	Collaborator 1
responsibility 2	Collaborator 2
...	...

Walkthroughs with CRC

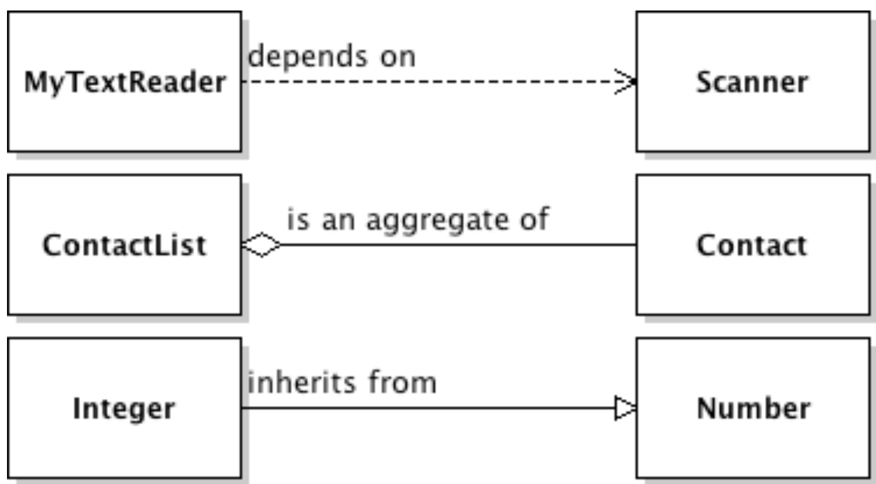
- Play out (partial) use cases using CRC
- Who does what during the use case?
- Do some objects have too much responsibility?
  - Create helper objects or agents
- Are some classes never used?

UML Class Diagrams

- Each class is a rectangle



- Connect classes by their relationship

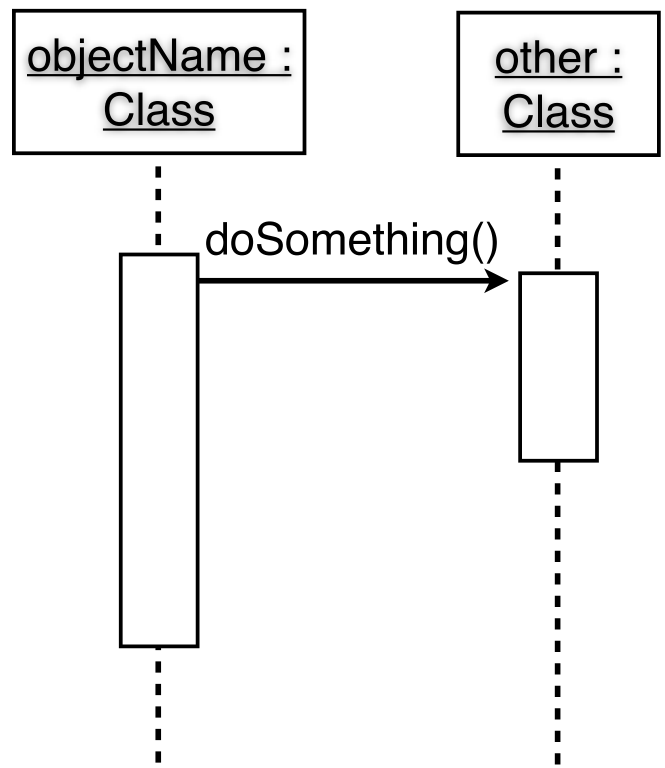


Class Relationships

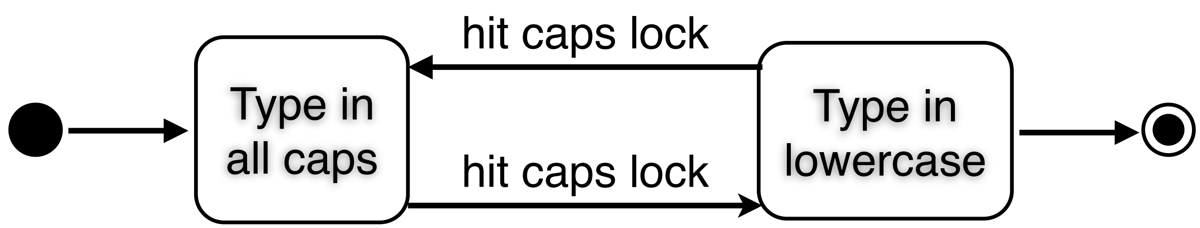
- **Dependency** - any time one class needs the other
- **Aggregation** - one class contains elements of the other class
- **Association** - other relationship
- **Inheritance**
- **Interface Implementation**

Sequence Diagrams

- Draw objects as they interact over time
- UML: underline to indicate instances
- Each object has dotted life-line
- **Activation bars** indicate object running
- Arrows indicate method calls

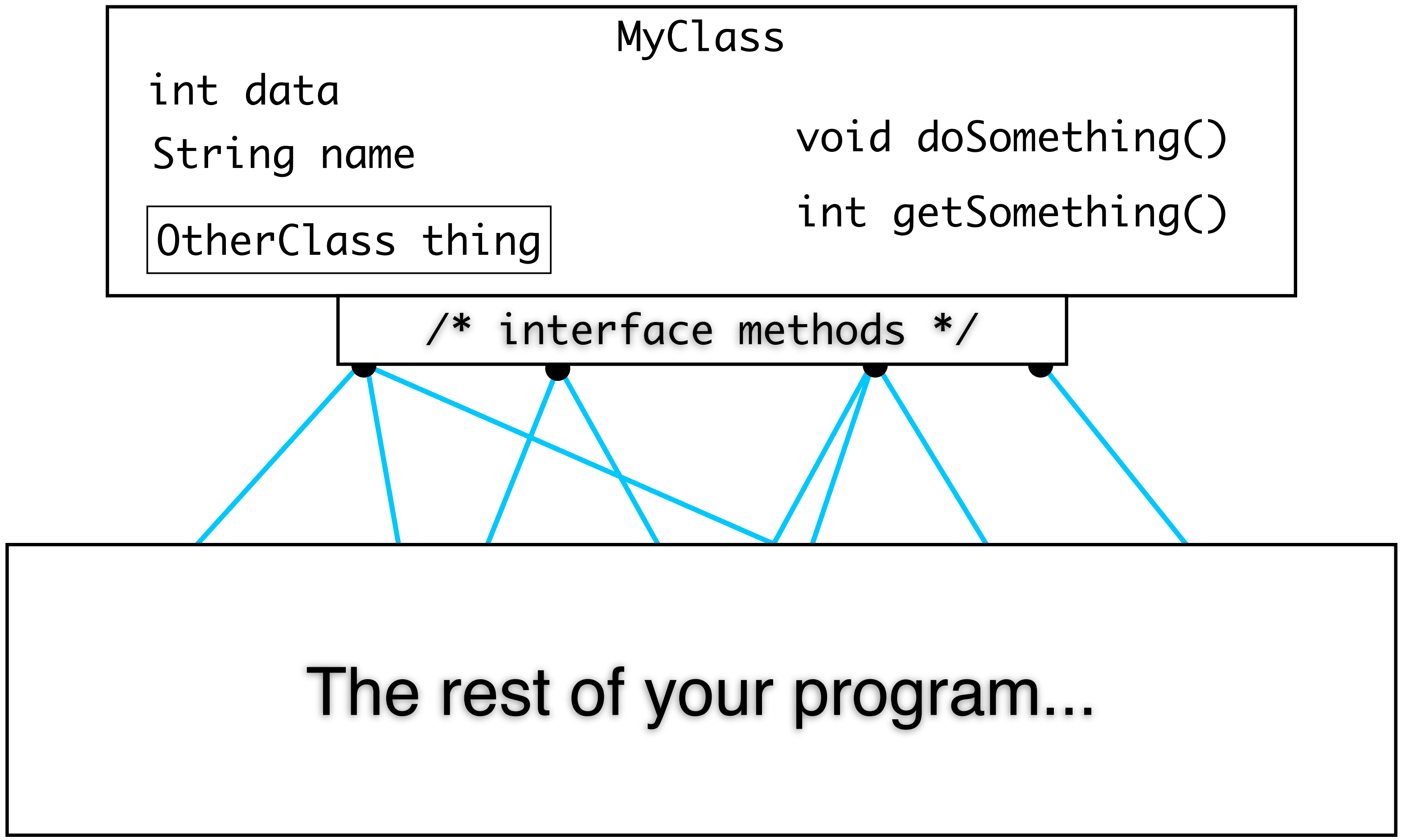


State Diagrams



- Useful for visualizing how an object changes over time
- Rounded rectangles represent states
- Arrows and text describe triggers for state changes

Why Encapsulation?



Encapsulation

Why Encapsulation?

- Easier changes to implementation
- Control of inputs and outputs
- Less old code to have to maintain when updating
- When changes are made, easier to find what code is affected

Good Interfaces

- **Cohesion** - represent only one concept
- **Completeness** - does everything you'd expect
- **Convenience** - some syntactic sugar,

  `BufferedReader(new InputStreamReader(System.in))`
- **Clarity** - behavior of class should be easy to explain accurately
- **Consistency** - naming conventions, etc

Accessors vs. Mutators

- Methods to handle data members
- **Accessors** for reading
- **Mutators** for writing/modifying
- Keep them separate

Side Effects

- Avoid methods with side effects
- Calling accessors repeatedly should yield same result
  - counterexample: Scanner.nextLine()
- Mutators should change things in an obvious way

Programming by Contract

- Another formalism to help organization
- All methods and classes have "contracts" detailing responsibilities
- Contracts expressed as **preconditions**, **postconditions**, and **invariants**

Preconditions

- Condition that must be true before method is called
  - e.g., indices must be in range, objects must not be null
- Limits responsibilities of your method

Postconditions

- Conditions guaranteed to be true after method runs
  - e.g., after calling sort(), ToDoList elements are sorted by due date
- Useful when in addition to @return tags
  - I.e., usually involves mutators or side effects

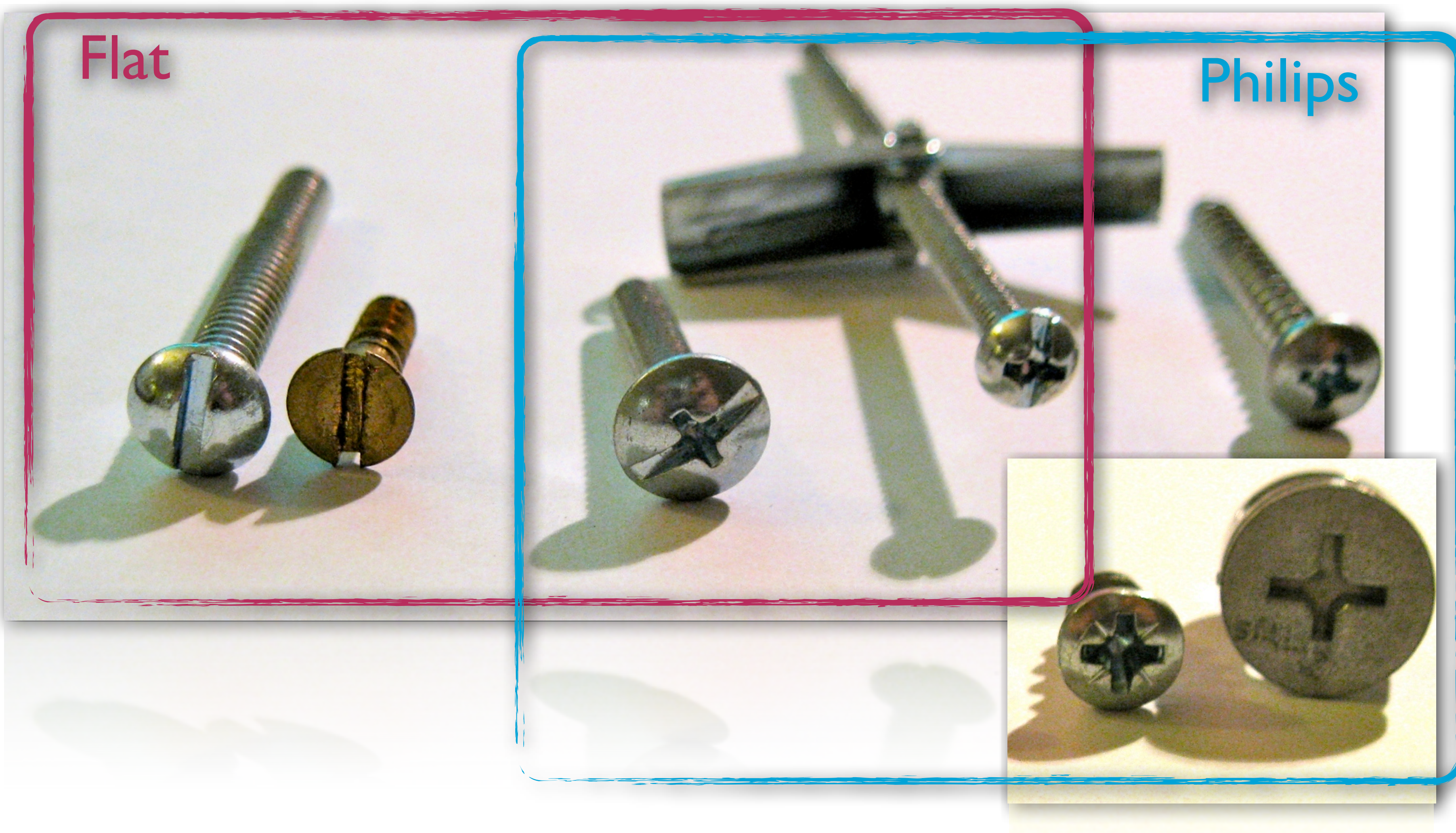
Invariants

- General properties of any member of a class that are always true
  - e.g., ToDoList is always sorted
- *Implementation invariants* are useful when building the class
- *Interface invariants* are useful when using the class

Why Interfaces?

- Interchangeable parts are essential in modern engineering
- Allows tools and parts to be used for various applications
- Without establishing standard interfaces, every part must be custom-built for each application

Interfaces of Screws



Iterator Interface

- An Iterator<T> lets you look at one element at a time from a Collection<T>
- boolean hasNext(), T next()
- Using Iterators, you can write code that doesn't know what kind of Collection you have

Iterators Preserve Encapsulation

- Iterator user doesn't know how the items are stored
- Iterating through linked list:
  - Do work on current node
  - Go to current.next()
- Need to know linked list structure, and private next() links

Programming Patterns

- Patterns are defined by a general **context**, the design challenge
- And a **solution**, which prescribes how to design your program in the context
- Since patterns are general, they will feature many interfaces

Iterator: Context

- An aggregate object contains element objects
- Clients need access to the elements
- The aggregate should not expose its internal structure
- There may be multiple clients that need simultaneous access

Iterator: Solution

- Define an iterator class that fetches on element at a time
- Each iterator object keeps track of the position of the next element to fetch
- If there are variations of the aggregate and iterator class, implement common interface types.

Patterns in GUI Programming

- We saw in our example GUI programs that GUI code can get messy
- Thus, there are many useful patterns people have established for GUIs

Model-View-Controller

- Context: GUI displays some data that the user can affect via GUI
- Solution: separate objects into a model, a view and a controller
  - Model - stores the data
  - View - displays the data from Model
  - Controller - maps user actions to model updates

MVC Responsibilities

Model

Stores text and formatting markup (fonts, sizes, colors)

Notifies View to update when Model changes

View

Displays text with proper fonts and sizes

Displays toolbar

Notifies Controller when user edits text or clicks toolbar commands

Controller

Notifies model to change text when user inputs

Notifies model to perform special commands when toolbar buttons are clicked

Pattern: Observer

Context

- A *subject* object is the source of events
- One or more *observer* objects want to know when an event occurs

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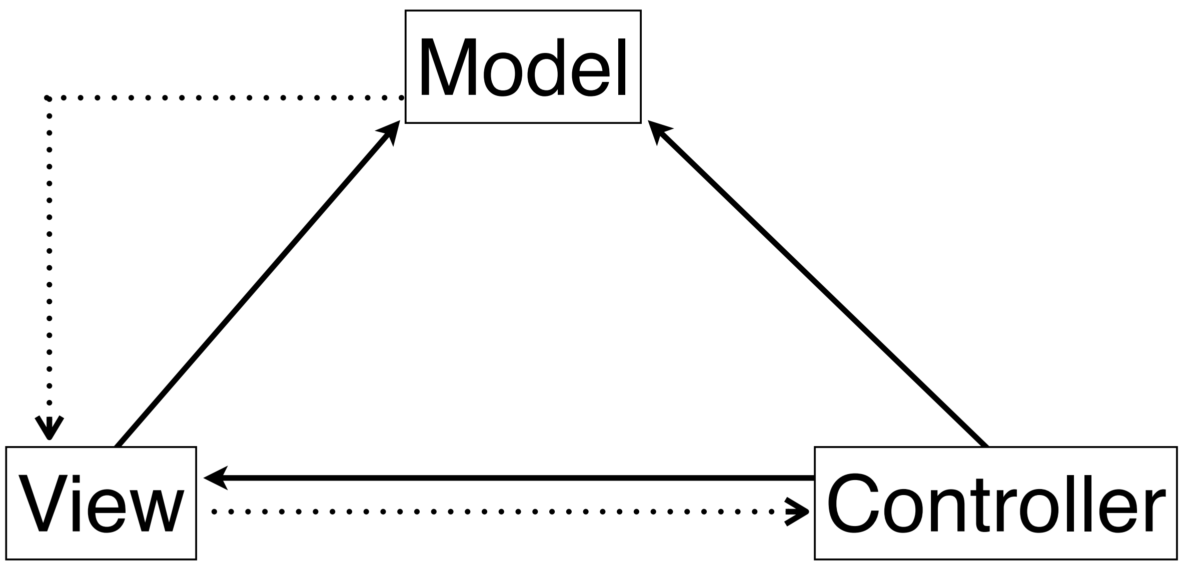
Solution

- Define an *observer* interface type
- The *subject* maintains collection of *observer* objects
- The *subject* provides methods for attaching *observers*
- Whenever an event occurs, the subject notifies all *observers*

Observers in MVC

- View observes Model; when Model changes, it notifies View
- Controller observes View; when user manipulates View, it notifies Controller



Pattern: Composite

- Primitive objects can be combined into composite objects
- Clients treat a composite object as a primitive object

- Define an interface type that abstracts primitive objects
- Composite object contains a collection of primitive objects
- Both primitive and composite classes implement interface
- When implementing methods from the interface, composite class applies method to its primitive objects and combines the results

Pattern: Decorator

- You want to enhance the behavior of a component class
- A decorated component can be used in the same way as a plain component
- The component class shouldn’t be responsible for the decoration
- There may be an open-ended set of possible decorations

- Define an interface type that abstracts the component
- Concrete component classes implement this interface
- Decorator classes also implement this interface
- Decorator objects manage the component that it decorates

Pattern: Strategy

- A *context* class benefits from different variants of an algorithm
- Clients of the *context* class sometimes want to supply custom versions of the algorithm

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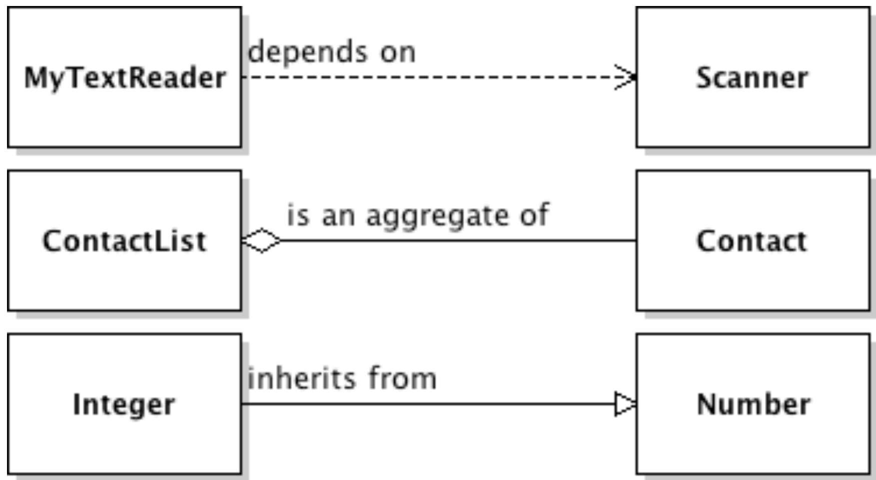
- Define an interface type, called a *strategy,* that abstracts the algorithm
- Each concrete *strategy* class implements a version of the algorithm
- The client supplies a concrete strategy object to the context class
- Whenever the algorithm needs to be executed, the context class calls the appropriate methods of the strategy object

Inheritance



- Describes a relationship between classes in which a *subclass* is a more specific form of a *superclass*
- Declared in Java with the keyword `extends`

Subclasses

- Subclasses often provide additional methods and fields
  - or they may *override* the superclass's methods
- Java allows special keyword `super` to refer to superclass
  - used to invoke superclass's methods, including constructor

Liskov's Substitution Principle

- Let *q(x)* be a property provable about objects *x* of type *T*. Then *q(y)* should be true for objects *y* of type *S* where *S* is a subtype of *T*. (Liskov)
- You can substitute subclass objects whenever a superclass object is expected
  - but not always vice versa (never)

Polymorphism and Inheritance

- Overriding methods can cause some confusion if we're unclear on how inheritance works
- We extended MouseAdapter to make MyMouseListener
- ```
  MouseAdapter ma = new MyMouseListener();
  ma.mouseClicked(); // what happens?
  ```
- Actual types of objects, not declared types, determine which methods are called
  ```

Encapsulation and Inheritance

- Public and private modifiers apply even to subclasses
  - Extending a class doesn't grant you access to its private methods
- Otherwise, implementations would not be interchangeable, since subclasses would depend on private class code
- Subclasses must implement their added functionality using only public interface of superclass

Preconditions and Postconditions

- Subclass methods cannot have stricter preconditions than superclass methods
- Subclass methods cannot have looser postconditions than superclass methods
- Because all subclass objects must fit Liskov substitution; they must be viewable as superclass objects

Inheritance

- Subclasses inherit methods and fields from superclasses
- Analogous to taxonomies
- In Java and most languages, subclasses can only inherit from one superclass

Abstract Classes

- Abstract classes are meant to be extended by various subclasses
- The abstract class can never be instantiated
- but methods and fields can be defined and implemented
- A subclass can only extend one abstract class

Pattern: Template Method

- An algorithm is applicable for multiple types
- The algorithm can be broken down into *primitive operations*. The primitive operations can be different for each type
- The order of the primitive operations in the algorithm doesn't depend on the type

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- Define an abstract superclass that has a method for the algorithm and abstract methods for the primitive algorithms
- Implement algorithm to call primitive operations in order
- Leave primitive operations abstract or have basic default
- Each subclass defines primitive operations but not the algorithm

Types

- Programming languages organize variables into types
- Classes are related, but don't tell the whole story
- Types include primitives and classes
- Java is a *strongly typed* language: many compiler checks to validate type usage

Types in Java

- Types in Java are either
  - A primitive type
  - A class type
  - An interface type
  - An array type
  - The null type

Values in Java

- Values in Java are either
  - A primitive value (int, double, etc.)
  - A reference to an object of a class
  - ” ”
  - A reference to an array
  - null

Reading

- Horstmann Ch. 2.1 - 7.4
  - Skim code, focus on concepts