CS 5004: OBJECT ORIENTED DESIGN AND ANALYSIS

SPRING 2022

LECTURE 10

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AGENDA

- Review – Java Collections Framework
  - Interfaces Iterator, Comparable and Comparator
  - Inner and nested classes
- Maps and Hashing
- Design of programs

JAVA COLLECTIONS FRAMEWORK

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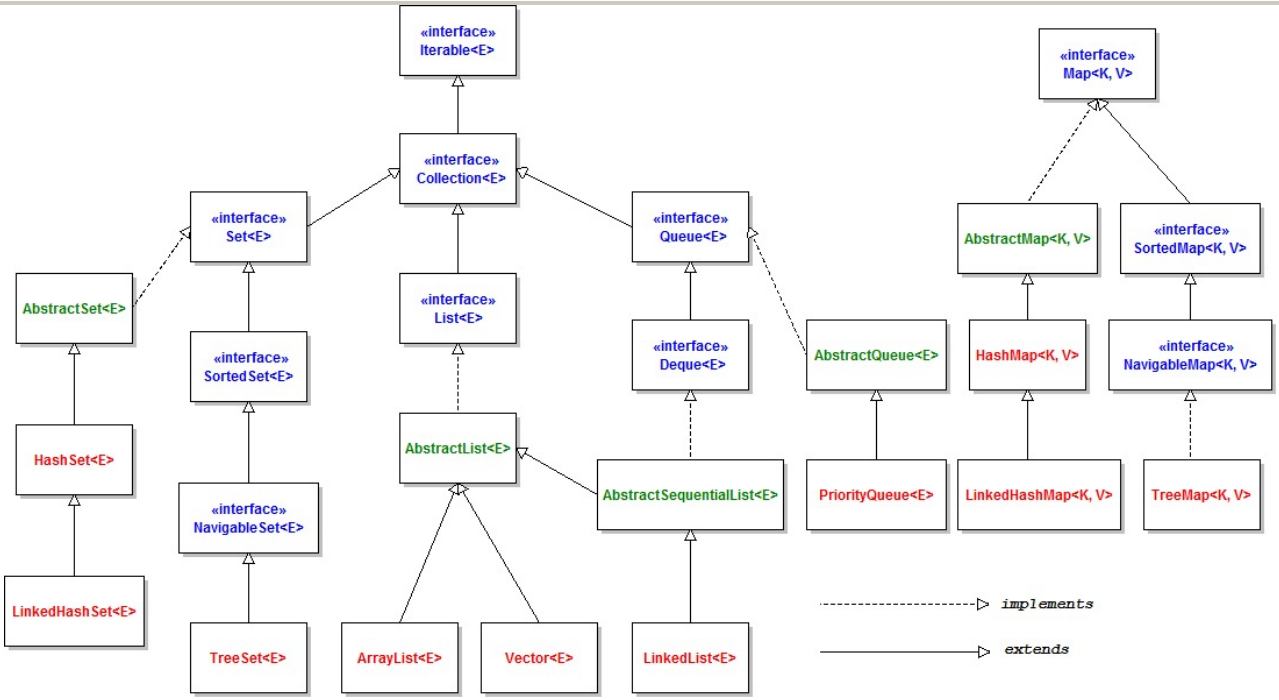
ONCE AGAIN: JAVA COLLECTIONS FRAMEWORK



[Pictures credit: http://www.codejava.net]

REVIEW: INTERFACE ITERABLE<T>

- Super-interface for interface `Collection<T>`
- Implementing interface `Iterable<T>` allows an object to be traversed using the for each loop
- Every object that implements `Iterable<T>` must provide a method `Iterator iterator()`

Modifier and Type	Method and Description
`default void`	**`forEach(Consumer<? super T> action)`** Performs the given action for each element of the `Iterable` until all elements have been processed or the action throws an exception.
`Iterator<T>`	**`iterator()`** Returns an iterator over elements of type T.
`default Spliterator<T>`	**`spliterator()`** Creates a **`Spliterator`** over the elements described by this `Iterable`.

REVIEW: INTERFACE ITERABLE<T> AND ITERATOR<E>

- Super-interface for interface `Collection<T>`
- Every object that implements `Iterable<T>` must provide a method `Iterator iterator()!`

- Interface `Iterator` – an iterator over a collection

```
public interface Iterator<E> {
   boolean hasNext();
   E next();
   void remove():
}
```

- Iterator `remove()` method – removes the last item returned by method `next()`

REVIEW: INTERFACE COMPARABLE<T> - TEMPLATE

```
public class name implements Comparable<name> {

    ...

    public int compareTo(name other) {
        ...
    }
}
```

METHOD COMPARE (T O1, T 02)

- `int compare(T o1, T o2)` - compares its two arguments for order and returns:
  - A negative integer if the first argument is less than the second
  - Zero, if the first argument is equal to the second
  - A positive integer if the first argument is greater than the second
- The implementor must also ensure that the relation is transitive:

  ```
  ((compare(x, y) > 0) && (compare(y, z) > 0)) implies compare(x, z) > 0
  ```

- Not strictly required, but good rule to follow: `compare()` method should be consistent with `equals()` method:

  ```
  (compare(x, y)==0) == (x.equals(y))
  ```

  (Any comparator that violates this condition should clearly indicate this fact. The recommended language is "`Note: this comparator imposes orderings that are inconsistent with equals.`") (don't do this!)

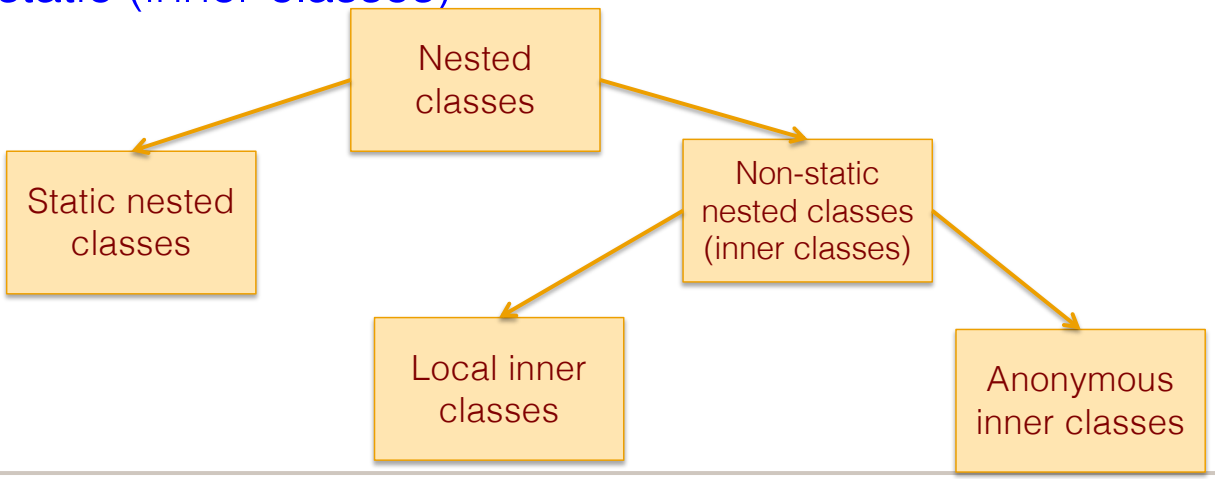
REVIEW: INTERFACE COMPARATOR<T>

- Interface `Comparator<T>` - a comparison function, which imposes a total ordering on some collection of objects
  - Can be passed to a sort method, to allow precise control over the sort order
  - Can also be used to control the order of certain data structures (tree sets and tree maps)
  - Can also be used provide an ordering for collections of objects that don't have a natural ordering

REVIEW: NESTED CLASSES

- Nested class – a class defined within some other class

- Nested classes can be:
  - Static classes
  - Non-static (inner classes)



MAP AND HASHING

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MAPS

- Write a program that stores, modifies and retrieves:
  - Assignment grades for every student in this College
  - Financial information for every client of some bank
  - Browsing history for every user of some search engine
  - Searches and transactions for every user of some online retailer
  - Activity and likes of every user of some online platform

- Question: What do these records have in common?
- The way we think about them → every data sample has a unique user → unique ID (key)
- What is the appropriate data collection for this data?
- Maps

MAPS

- Map – a data collection that holds a set of unique *keys* and a collection of *values*, where each key is associated with one value
- Also known as:
  - Dictionary
  - Associative array
  - Hash
- Basic map operations:
  - **`put`**`(`*`key`*`, `*`value`*`)` - adds a mapping from a key to a value
  - **`get`**`(`*`key`*`)` - retrieves the value mapped to the key
  - **`remove`**`(`*`key`*`)` - removes the given key and its mapped value

MAP IMPLEMENTATIONS

- In Java, maps are represented by `Map` type in `java.util`
- Map is implemented by the `HashMap` and `TreeMap` classes
  - `HashMap` - implemented using a "hash table"
    - Extremely fast: O(1)
    - Keys are stored in unpredictable order
  - `TreeMap` - implemented as a linked "binary tree" structure
    - Very fast: O(log N)
    - Keys are stored in sorted order
  - `LinkedHashMap` - O(1)
    - Keys are stored in order of insertion

MAP IMPLEMENTATIONS

- Map requires 2 types of parameters:
  - One for keys
  - One for values

- Example:

```
// maps from String keys to Integer values
Map<String, Integer> votes = new HashMap<String, Integer>();
```

MAP METHODS

`put(key, value)`	adds a mapping from the given key to the given value; if the key already exists, replaces its value with the given one
`get(`**`key`**`)`	returns the value mapped to the given key (`null` if not found)
`containsKey(`**`key`**`)`	returns `true` if the map contains a mapping for the given key
`remove(`**`key`**`)`	removes any existing mapping for the given key
`clear()`	removes all key/value pairs from the map
`size()`	returns the number of key/value pairs in the map
`isEmpty()`	returns `true` if the map's size is 0
`toString()`	returns a string such as "{a=90, d=60, c=70}"

KEYSET AND VALUES

- `keySet` method returns a **`Set`** of all keys in the map
  - It can loop over the keys in a `foreach` loop
  - It can get each key's associated value by calling `get` on the map

- Example:

```
Map<String, Integer> ages = new TreeMap<String, Integer>();
ages.put("Marty", 19);
ages.put("Geneva", 2); // ages.keySet() returns Set<String>
ages.put("Vicki", 57);
for (String name : ages.keySet()) {       // Geneva -> 2
   int age = ages.get(name);              // Marty -> 19
   System.out.println(name + " -> " + age); // Vicki -> 57
}
```

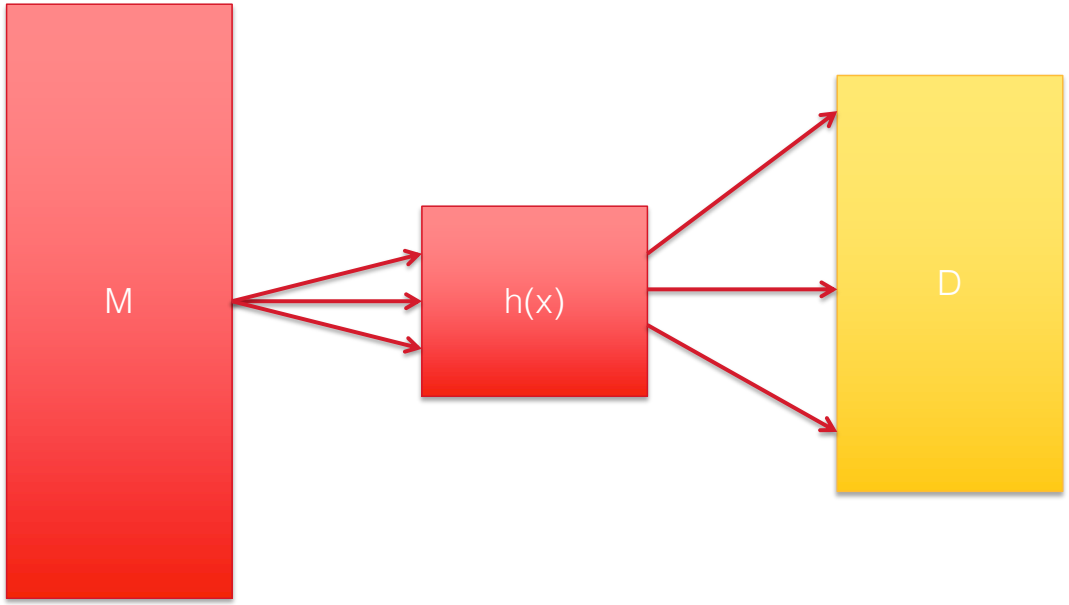
METHODS KEYSET AND VALUES

- `values` method returns a collection of all values in the map
  - It can loop over the values in a `foreach` loop
  - No easy way to get from a value to its associated key(s)

`keySet()`	returns a set of all keys in the map
`values()`	returns a collection of all values in the map
`putAll(`**`map`**`)`	adds all key/value pairs from the given map to this map
`equals(`**`map`**`)`	returns `true` if given map has the same mappings as this one

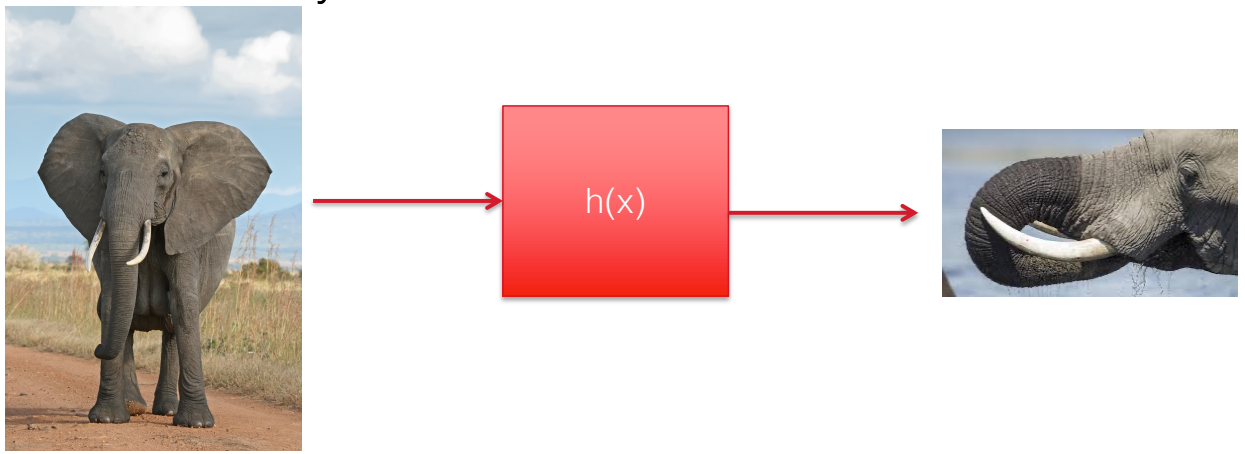
INTRODUCTION TO HASHING

- Mimicking a buddy – pseudo-random mapping using a hash function h(x)



INTRODUCTION TO HASHING

- Hash function:
  - Maps search space M into target space D
  - Map data of arbitrary size onto data of a **fixed size**



[Pictures credit: https://upload.wikimedia.org/wikipedia/commons/3/37/African_Bush_Elephant.jpg
https://aos.iacpublishinglabs.com/question/aq/1400px-788px/what-are-elephant-tusks-used-for_3c174bec-bd85-4fab-a617-7a1a33f14c62.jpg?domain=cx.aos.ask.com]

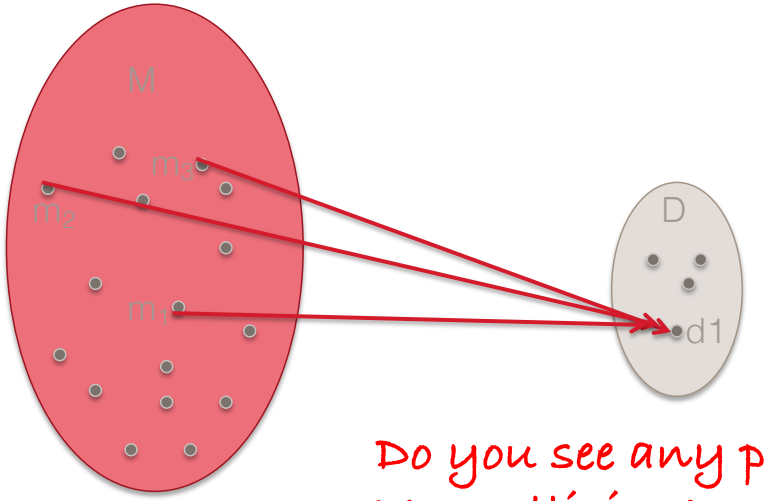
INTRODUCTION TO HASH FUNCTIONS

- Hash function – Map data of arbitrary size onto data of a fixed size

- Desired properties of hash functions:
  - Repeatability:
    - For every x in D, it should always be h(x) = h(x)
  - Equally distributed:
    - For some y, z in D, P(h(y)) = P(h(z))
  - Constant-time execution: h(x) = O(1)

PROBLEMS WITH HASH FUNCTIONS

- Hash function – can be thought of as a "lossy compression function", since |M| << |D|



Do you see any problems here?
Yes, collision!

RESOLVING COLLISIONS

- Hash function – can be thought of as a "lossy compression function", since |M| << |D|
- Problem – collision

- Possible approaches to resolve collisions:
  - Store data in the next available space
  - Store both in the same space
  - Try a different hash
  - Resize the array

DESIGN OF PROGRAMS

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ACKNOWLEDGEMENT

Notes inherited and modified from the original notes prepared by Professors: Hal Perkins, Jonathan Aldrich, Abi Evans and Tony Mullen. Thank you.

DESIGNING SOFTWARE

- Design is *creative* problem solving
  - No surefire recipe for success
  - Learn from others' experience
  - Following known best practices is a a significant success factor

DESIGN PROBLEM FORMULATION

- How to decompose a system into parts, each with a lower complexity of the whole system, such that:
  - Interaction between parts is minimized
  - Combination of the parts together solves the problem

- No universal way to do this!
- Some rules of thumb:
  - Don't think of the system in terms of components that correspond to steps in processing: This adds complexity
  - Do provide a set of modules that are useful for writing many programs. Plan for reuse!

WHAT GOES WRONG WITH SOFTWARE?

- *But then something begins to happen. The software starts to rot. At first it isn't so bad. An ugly wart here, a clumsy hack there, but the beauty of the design still shows through. Yet, over time as the rotting continues, the ugly festering sores and boils accumulate until they dominate the design of the application. The program becomes a festering mass of code that the developers find increasingly hard to maintain.*

Robert C. Martin, Design Principles and Design Patterns

ROTTING SOFTWARE DESIGN

- Symptoms
  - **Rigidity**: hard to change
  - **Fragility**: breaks easily
  - **Immobility**: hard to reuse code
  - **Viscosity**: structure breaks down

- Causes
  - Changing requirements
  - Dependency management

WELL DESIGNED OBJECT-ORIENTED SYSTEMS

- Object-oriented principles
  - Encapsulation
  - Abstraction
  - Information hiding
  - Polymorphism
  - Inheritance

WELL DESIGNED OBJECT-ORIENTED SYSTEMS

- SOLID principles - intended to make code more understandable, maintainable and flexible

- Single responsibility – related to encapsulation
- Open-closed – related to abstraction and inheritance
- Liskov substitution – related to polymorphism
- Interface segregation – related to encapsulation
- Dependency inversion – related to abstraction

WELL DESIGNED OBJECT-ORIENTED SYSTEMS

- S – Single responsibility principle
  - (one class, one responsibility)
- O – open closed principle
  - (open for extension, closed for modification)
- L – Liskov substitution principle
  - (derived classes must be substitutable for their base classes)
- I – Interface segregation principle
  - (no client should be forced to depend on methods it does not use)
- D – Dependency inversion principle
  - (details should depend on abstraction, not the other way around)

MODULAR DESIGN

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MODULAR DESIGN

- Idea: split code into interchangeable, reusable components
  - "Mix-and-match"

[Picture credit: cdn.shopify.com/]

MODULAR DESIGN

- Module: some part of a program responsible for a specific area of functionality, and designed to interact with other modules

- Modular design regards modules as design units
  - Focus on:
    1. How modules are specified?
    2. What functionality they govern?
    3. How modules interact?

IDEALS OF MODULAR DESIGN

- Decomposition: break a problem into modules to reduce complexity and enable teamwork
- Composability: put modules together, ideally in various way
- Understandability: a module should be understandable without reference to other modules
- Continuity: small change in requirements should be answerable by small (local) change in design
- Isolation: contain errors and enable independent development

COHESION AND COUPLING

- Object-oriented design seeks to **maximize** cohesion, while **minimizing** coupling

- Cohesion
  - How well a module (class) encapsulate a single responsibility → **does everything in the class belong to the class?**

- Coupling
  - Interdependencies between classes → **does a class depend on some other class to be operational?**

DECOUPLING AND DESIGN

- Goal: avoid unnecessary coupling

- Approach: examine dependencies before coding (in design phase)
  - Coding without first analyzing dependencies will likely lead to unnecessary coupling
  - A method needs access to information from other objects, but…
    - Naïve solutions lead to tight coupling
    - Tight coupling leads to code that it harder to understand and reuse

DIFFERENT TYPES OF COUPLING

- Content coupling
  - One class is highly dependent on another, and may modify its internal states
- Common coupling
  - Multiple classes share common data
- Control coupling
  - Using flags / logic to allow client code to control how a method behaves
- Stamp coupling
  - Another object is passed as a parameter
- Data coupling
  - Too many parameters

DIFFERENT TYPES OF COUPLING

- Content coupling
  - One class is highly dependent on another, and may modify its internal states
  - Always bad!
  - Fix: don't modify internal states of other objects

- Common coupling
  - Multiple classes share common data
  - Changes to the common data affects all objects that use it
  - Not always a problem

DIFFERENT TYPES OF COUPLING

- Control coupling
  - Using flags / logic to allow client code to control how a method behaves
  - Client code needs to know about the methods implementation
  - Fix: Separate method (or use polymorphism, if applicable)

```
public String getName(boolean fullName) {
  if (fullName)
    return this.firstName + " " + this.lastName;
  else
    return this.firstName;
}
```

DIFFERENT TYPES OF COUPLING

- Control coupling
  - Using flags / logic to allow client code to control how a method behaves
  - Client code needs to know about the methods implementation
  - Fix: Separate method (or use polymorphism, if applicable)

```
public String getFirstName() {
  return this.firstName;
}

public String getFullName() {
 return this.firstName + " " + this.lastName;
}
```

Fix: Separate methods (or polymorphism if applicable)

DIFFERENT TYPES OF COUPLING

- Stamp coupling
  - Another object is passed as a parameter
  - Fix: use primitive data types as parameters, when possible

- Data coupling
  - Too many parameters. Rule of thumb - more than 3 is too many
  - Fix: encapsulate related parameter into an object
    - Caveat: this can potentially cause stamp coupling

DESIGN AND DECOUPLING

- Always avoid content coupling
- For other forms of coupling
  - Be aware that they exist
  - Reduce and remove them if it makes sense
  - If you can't remove/reduce – take steps to minimize side effects

BENEFITS OF LOOSE COUPLING

- Design decisions in one class do not affect other classes
- Correctness is easier to demonstrate through testing
- Increased reusability
- Easier maintenance
  - Less likely that changes will impact other parts of a program
  - More robust to errors

GENERAL GOOD DESIGN TIPS

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GENERAL GOOD DESIGN TIPS

- Methods - should do one thing well
  1. Compute a value, but let the client decide what to do with it (e.g. don't calculate a value and put it in a String)
  2. Observe or mutate, but not both
  3. "Flag" variables to control behavior are often a symptom of poor design
     - *Often* bad, not *always* bad
     - Can you use polymorphism to remove the need for a flag?
     - Can you split the method into separate, smaller, more specific methods?

GENERAL GOOD DESIGN TIPS

- Methods - should do one thing well
  - Avoid long parameter lists → error prone and confusing
  - Be careful with overloading
    - Only overload if methods truly are related

GENERAL GOOD DESIGN TIPS

- Instance variables
  - A variable should be made into an instance if and only if:
    - It is a part of the inherent internal state of an object
    - It has a value that is meaningful for the object's entire life
    - Its state must persist past the end of any of the methods
  - All other variables can be local to the methods in which they are used

GENERAL GOOD DESIGN TIPS

- Constructors
  - Object should be completely initialized after the constructor is called
    - Client code should not be forced to use other methods to finish initialization
  - Constructors can be private/protected
    - Use when there is a reason for tighter control of object initialization

PATTERNS IN SOFTWARE DEVELOPMENT

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PATTERNS IN SOFTWARE DEVELOPMENT

- Established approaches to solving common problems
- Enable us to draw on others' experience
- Enable a common vocabulary to discuss abstract problem-solving concepts
- Various degrees of granularity/specificity

WHAT IS A PATTERN

- Patterns are for developers
- What patterns are most important depend on the problem domain, programming language, and paradigm
  - Encapsulation and inheritance may be regarded as patterns in procedural languages, while in OOP, they are built in to the language.
  - Monads, applicatives, and functors are patterns in functional programming
  - "Design patterns" terminology strongly associated with object-oriented design

PATTERNS IN SOFTWARE DEVELOPMENT

- Architectural patterns
  - Broad scope/application-wide organization
  - May be concerned with hardware limitations, business risk, etc.
  - Can provide conceptual foundations of frameworks
- Design patterns
  - Narrower, more specific scope than architectural patterns
  - Established, reusable solutions to specific implementation problem
  - Language independent, at least within a fixed paradigm (strongly associated with OOP)
  - Principled approaches to addressing classes of problems

ARCHITECTURAL PATTERNS

- Heavily problem-domain oriented
  - Client/server pattern for networked applications
  - Peer-to-peer pattern for networked applications
  - Layered patterns (e.g. OSI layers, TCP/IP layers) for network communication
  - Microservices/serverless pattern for cloud computing
  - Blackboard pattern for integrating various information sources to determine complex, non-deterministic control (autonomous agents, speech recognition)

DESIGN PATTERNS

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DESIGN PATTERNS - HISTORY

"Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice."

Christopher Alexander

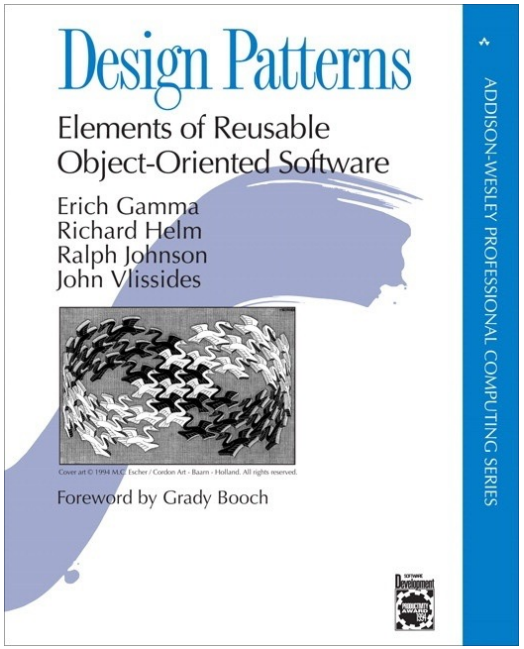
DESIGN PATTERNS - HISTORY

Christopher Alexander, *The Timeless Way of Building* (and other books)

- Proposes patterns as a way of capturing design knowledge in architecture
- Each pattern represents a tried-and-true solution to a design problem
- Typically an engineering compromise that resolves conflicting forces in an advantageous way

DESIGN PATTERNS - HISTORY

- The Gang of Four (GoF) - Seminal book Design Patterns
- Descriptions of communicating objects and classes that are customized to solve a general design problem in a particular context



[Picture credit: https://www.quora.com]

DESIGN PATTERNS

- There are many commonly occurring problems in software development
- Design patterns can be thought of as templates for solving these
- They are:
  - Time tested and proven
  - Easily re-used
  - Expressive and understandable

DESIGN PATTERNS – OTHER BENEFITS

- They can reduce the amount of code by reducing repetition
- They encapsulate the wisdom and experience of past developers
- They provide a vocabulary for communicating about software problems and solutions
- They enable developers to focus less on general issues of how to structure the software and more on the quality of the implementation

ELEMENTS OF A DESIGN PATTERN

- Name
  - Important because it becomes part of a design vocabulary
- Problem
  - When the pattern is applicable
- Solution
  - Design elements and their relationships
  - Abstract: must be specialized
- Consequences
  - Tradeoffs of applying the pattern
    - Each pattern has costs, as well as benefits
    - Issues include flexibility, extensibility, security…
    - There may be variations in the pattern with different consequences

TYPES OF DESIGN PATTERNS

- Creational design patterns - focus on ways to create or control the creation of objects
- Structural design patterns - focus on object composition, relations between objects (e.g. inheritance), and relations between objects and the system as a whole
- Behavioral patterns - focus on improving or streamlining communication between objects

CREATIONAL DESIGN PATTERNS

- Factory Method Pattern - write a method to return new instances of a class (or subclass, based on parameters sent to the method) without client object needing to call constructor directly
- Abstract Factory Pattern – a class that provides a family of factories to handle the responsibility of creating instances of subclasses
- Builder Pattern - a class that encapsulates a complex object creation process, e.g. including optional parameters
- Prototype Pattern - create objects by creating a prototypical instance and cloning new objects from that
- Singleton Pattern - create a single instance of a class. Constructor is private, called by a static method (*regarded by critics as an anti-pattern*)

STRUCTURAL DESIGN PATTERNS

- Adapter (wrapper) – a class to take objects of another class, and enable them to implement an interface that their original class does not implement
- Bridge - decouple an abstraction from its implementation so that the two can vary independently
- Composite - compose objects into tree structures to represent part-whole hierarchies. Enables clients to treat objects and compositions of objects uniformly.
- Decorator - attach additional behavior or responsibilities to an object dynamically. An alternative to subclassing for extending functionality

STRUCTURAL DESIGN PATTERNS - CONT

- Façade - provide a unified interface to a set of interfaces in a subsystem. Simplify use of a complex subsystem by wrapping it in a simpler, higher-level interface
- Flyweight - maintain state that is shared by multiple objects in its own container, rather than duplicating state across objects
- Proxy - create an object to hold the place of another object, able to carry out certain functionality on behalf of the original object, possibly in situations where the original object would not be available to do so.

BEHAVIORAL DESIGN PATTERNS

- Chain of Responsibility - build a sequence of handlers where each handler processes a request and decides whether to pass it on to the next handler
- Command - abstract multiple related processes (functions or methods) into a single process, distinguishing the original cases by parameters
- Iterator - separates the structure of a collection from the process of iterating over it by creating class that encapsulates a particular approach to traversing the collection. For example, a tree-structure collection may be associated with a depth-first iterator and a breadth-first iterator, and the appropriate one would be used to iterate through items in the tree structure.
- Mediator - a class that mediates communication between other classes. Simplifies potentially complex entanglements by routing all communications through the mediator.

BEHAVIORAL DESIGN PATTERNS

- Memento - create a representation of internal state (which can include private state) that can be used to restore the state of the original object
- Observer (publisher/subscriber) - enable multiple objects to respond to events or state changes on another object
- State - enable an object to change its behavior based on the state it's in
- Strategy - create classes representing separate algorithms for accomplishing a similar task (e.g. a route planning tool that works for bike, automobile, public transportation, or walk route planning)
- Template Method - design the skeleton of an algorithm in a superclass, but let subclasses determine the specifics of the implementation
- Visitor - implement functionality in separate classes that can "visit" objects of dissimilar classes and lend them consistent functionality.

SOME KNOWN PROBLEMS – EXAMPLE 1

Problem: Exposed fields can be directly manipulated

- Violations of the representation invariant
- Dependences prevent changing the implementation

Solution: Hide some components

- Constrain ways to access the object

Disadvantages:

- Interface may not (efficiently) provide all desired operations to all clients
- Indirection may reduce performance

SOME KNOWN PROBLEMS – EXAMPLE 2

Problem: Repetition in implementations

- Similar abstractions have similar components (fields, methods)

Solution: Inherit default members from a superclass

- Select an implementation via run-time dispatching

Disadvantages:

- Code for a class is spread out, and thus less understandable
- Run-time dispatching introduces overhead
- Hard to design and specify a superclass [as discussed]

SOME KNOWN PROBLEMS – EXAMPLE 3

Problem: To access all members of a collection, must perform a specialized traversal for each data structure

- Introduces undesirable dependences
- Does not generalize to other collections

Solution:

- The *implementation* performs traversals, does bookkeeping
- Results are communicated to clients via a standard interface (e.g., **`hasNext()`**, **`next()`**)

Disadvantages:

- Iteration order fixed by the implementation and not under the control of the client

SOME KNOWN PROBLEMS – EXAMPLE 4

Problem:

- Errors in one part of the code should be handled elsewhere
- Code should not be cluttered with error-handling code
- Return values should not be preempted by error codes

Solution: Language structures for throwing and catching exceptions

Disadvantages:

- Code may still be cluttered
- Hard to remember and deal with code not running if an exception occurs in a callee
- It may be hard to know where an exception will be handled

SOME KNOWN PROBLEMS – EXAMPLE 5

Problem:

- Well-designed (and used) data structures hold one type of object

Solution:

- Programming language checks for errors in contents
- `List<Date>` instead of just `List`

Disadvantages:

- More verbose types

CREATIONAL PATTERNS

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CREATIONAL PATTERNS

Constructors in Java are inflexible

1. Can't return a subtype of the class they belong to
2. Always return a fresh new object, never re-use one

Factories: Patterns for code that you call to get new objects other than constructors

– Factory method, Factory object, Prototype, Dependency injection

Sharing: Patterns for reusing objects (to save space *and* other reasons)

– Singleton, Interning, Flyweight

SINGLETON PATTERN

For some class C, guarantee that at run-time there is exactly one instance of C

- And that the instance is globally visible

First, *why* might you want this?

- What design goals are achieved?

Second, *how* might you achieve this?

- How to leverage language constructs to enforce the design

A pattern has a recognized *name*

- This is the *Singleton Pattern*

POSSIBLE REASONS FOR SINGLETON PATTERN

- One **`RandomNumber`** generator
- One **`KeyboardReader`**, **`PrinterController`**, etc…
- Have an object with fields/properties that are "like public, static fields" but you can have a constructor decide their values
  - Maybe strings in a particular language for messages

- Make it easier to ensure some key invariants
  - There is only one instance, so never mutate the wrong one

- Make it easier to control when that single instance is created
  - If expensive, delay until needed and then don't do it again

SINGLETON PATTERN – MULTIPLE APPROACHES

```
public class Foo {
  private static final Foo instance = new Foo();
  // private constructor prevents instantiation outside class
  private Foo() { … }
  public static Foo getInstance() {
    return instance;
  }
  … instance methods as usual …
}
```

Eager allocation of instance

```
public class Foo {
  private static Foo instance;
  // private constructor prevents instantiation outside class
  private Foo() { … }
  public static synchronized Foo getInstance() {
    if (instance == null) {
      instance = new Foo();
    }
    return instance;
  }
  … instance methods as usual …
}
```

Lazy allocation of instance

MOTIVATION FOR FACTORY PATTERN

Supertypes support multiple implementations

```
interface Matrix { ... }
class SparseMatrix implements Matrix { ... }
class DenseMatrix implements Matrix { ... }
```

Clients use the supertype (**`Matrix`**)

Still need to use a **`SparseMatrix`** or **`DenseMatrix`** constructor

- Must decide concrete implementation *somewhere*
- Don't want to change code to use a different constructor
- Factory methods put this decision behind an abstraction

USE OF FACTORY PATTERN

Factory

```
class MatrixFactory {
  public static Matrix createMatrix() {
    return new SparseMatrix();
  }
}
```

Clients call **`createMatrix`** instead of a particular constructor

Advantages:

- To switch the implementation, change only *one* place
- **`createMatrix`** can do arbitrary computations to decide what kind of matrix to make (unlike what's shown above)

DATEFORMAT FACTORY PATTERN

DateFormat class encapsulates knowledge about how to format dates and times as text

- Options: just date? just time? date+time? where in the world?
- Instead of passing all options to constructor, use factories
- The subtype created by factory call need not be specified

```
DateFormat df1 = DateFormat.getDateInstance();
DateFormat df2 = DateFormat.getTimeInstance();
DateFormat df3 = DateFormat.getDateInstance
                    (DateFormat.FULL, Locale.FRANCE);

Date today = new Date();

df1.format(today)  // "Jul 4, 1776"
df2.format(today)) // "10:15:00 AM"
df3.format(today));// "jeudi 4 juillet 1776"
```

STRUCTURAL PATTERNS

CS 5004, SPRING 2022 – LECTURE 10

STRUCTURAL PATTERNS

A wrapper translates between incompatible interfaces

Wrappers are a thin veneer over an encapsulated class

- Modify the interface
- Extend behavior
- Restrict access

The encapsulated class does most of the work

Pattern	Functionality	Interface
Adapter	**same**	**different**
Decorator	**different**	**same**
Proxy	**same**	**same**

Some wrappers have qualities of more than one of adapter, decorator, and proxy

ADAPTER PATTERN

Change an interface without changing functionality

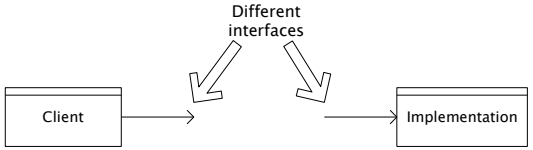
- Rename a method
- Convert units
- Implement a method in terms of another

Example: angles passed in radians vs. degrees

Example: use “old” method names for legacy code

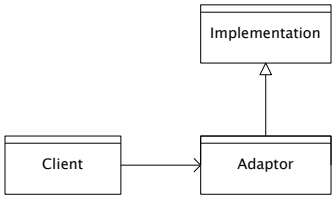
TYPES OF ADAPTER PATTERN

Goal of adapter:
connect incompatible interfaces

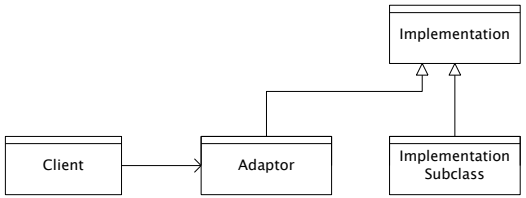


Adapter with delegation

Adapter with subclassing



Adapter with subclassing:
no extension is permitted



ADAPTER PATTERN - EXAMPLE

We have this **Rectangle** interface

```
interface Rectangle {
  // grow or shrink this by the given factor
  void scale(float factor);
  ...
  float getWidth();
  float area();
}
```

Goal: client code wants to use this library to "implement" **Rectangle** without rewriting code that uses **Rectangle**:

```
class NonScaleableRectangle { // not a Rectangle
  void setWidth(float width) { ... }
  void setHeight(float height) { ... }
   // no scale method
  ...
```

ADAPTER PATTERN: USE SUBCLASSING

```
class ScaleableRectangle1
                extends NonScaleableRectangle
                implements Rectangle {
  void scale(float factor) {
    setWidth(factor * getWidth());
    setHeight(factor * getHeight());
  }
}
```

ADAPTER PATTERN: USE DELEGATION

Delegation: forward requests to another object

```
class ScaleableRectangle2 implements Rectangle {
  NonScaleableRectangle r;
  ScaleableRectangle2(float w, float h) {
    this.r = new NonScaleableRectangle(w,h);
  }

  void scale(float factor) {
    r.setWidth(factor * r.getWidth());
    r.setHeight(factor * r.getHeight());
  }

  float getWidth() { return r.getWidth(); }
  float circumference() {
     return r.circumference();
  }
  ...
```

ADAPTER PATTERN: SUBCLASSING VS. DELEGATION

Subclassing

- automatically gives access to all methods of superclass
- built in to the language (syntax, efficiency)

Delegation

- permits removal of methods (compile-time checking)
- objects of arbitrary concrete classes can be wrapped
- multiple wrappers can be composed

REFERENCES AND READING MATERIAL

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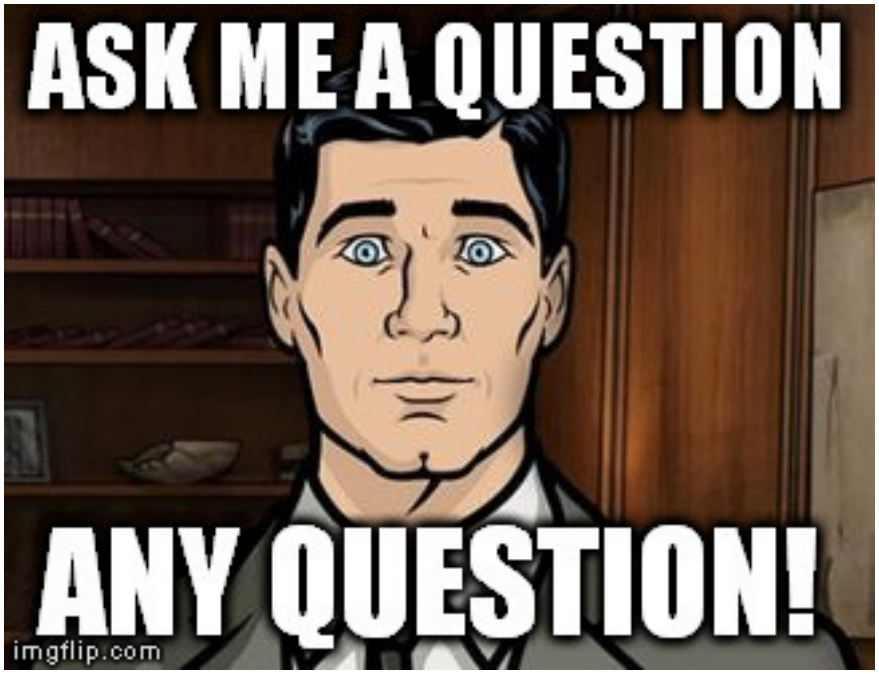
YOUR QUESTIONS



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