General Tips

Functional:

- Invariants that can be used to prove function

Administrative:

- small informative variables
- Comments in function definition, if, while, for, etc.
- pre/post conditions, loop invariant
- input/output types
- test null and all possible inputs (and outputs)
- Initial a variables you get from else where as null then get them (just in case there's an issue getting them) and test if null

Proving code:

- Preconditions, postconditions, assertions, loop invariants
- connect algorithmic ideas to imperative programs
- proofs + contracts = correctness and safety of code

Software Design

Software design and complexity:

- scale
- environment (I/O, Network)
- infrastructure (libraries, frameworks)
- evolution (design for change)
- correctness (testing, analysis tools, automation)

software qualities:

- sufficiency/func correctness
- robustness
- flexibility
- reusability
- efficiency
- scalability
- security

A simple process:

- Discuss the software that needs to be written
- Write some code
- Test the code to identify the defects
- Debug to find causes of defects
- Fix the defects
- If not done, return to first step

design tips:

- Think before coding
- Consider quality attributes (maintainability,extensibility, performance)
- Consider alternatives and make conscious design decisions

Preview: The design process:

- ObjectOriented Analysis
  - Understand the problem
  - Identify the key concepts and their relationships
  - Build a (visual) vocabulary
  - Create a domain model (aka conceptual model)
- ObjectOriented Design
  - Identify software classes and their relationships with class diagrams
  - Assign responsibilities (attributes, methods)
  - Explore behavior with interaction diagrams
  - Explore design alternatives
  - Create an object model (aka design model and design class diagram) and interaction models
- Implementation
  - Map designs to code, implementing classes and methods

Objects:

- A package of state (data) and behavior (actions)
- Can interact with objects by sending messages
  - perform an action (e.g., move)
  - request some information (e.g., getSize)
- Possible messages described through an interface

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sources:

- `http://www.cs.cmu.edu/~charlie/courses/15-214/2015-fall/index.html#schedule`

Design for Change

Design principle for change: information hiding:

- expose little implementation as possible
- allows you to change hidden details later

Subtype Polymorphism:

- There may be multiple implementations of an interface
- Multiple implementations coexist in the same program
- May not even be distinguishable
- Every object has its own data and behavior

Interface:

- can implement start (defining required methods and classes)
- create class to implement interface

What to test:

- Functional correctness of a method (e.g.,computations, contracts)
- Functional correctness of a class (e.g., class invariants)
- Behavior of a class in a subsystem/multiple subsystems/the entire system
- Behavior when interacting with the world
  - Interacting with files, networks, sensors,
  - Erroneous states
  - Nondeterminism, Parallelism
  - Interaction with users
- Other qualities (performance, robustness, usability, security,)

Unit Tests (Junit good for JAVA):

- Unit tests for small units: functions, classes, subsystems
  - Smallest testable part of a system
  - Test parts before assembling them
  - Intended to catch local bugs
- Typically written by developers
- Many small, fastrunning, independent tests
- Little dependencies on other system parts or environment
- Insufficient but a good starting point
- extra benefits:
  - Documentation (executable specification)
  - Design mechanism (design for testability)

Test cases strategies:

- use specs
- representative cases
- invalid cases
- boundary cond
- think like attacker
- dificult cases

static methods:

- Static methods belong to a class
- global
- Direct dispatch, no subtype polymorphism
- Avoid unless really only a single implementation exists (e.g., Math.min)

Best practices:

- control access
  - fields not accessible from client code
  - methods only accessible in exposed interface
- contracts - agreement between provider and user
  - interface specification
  - functionality and correctness expectations
  - Performance expectations
- Visibility Modifiers
  - design principle for change: information hiding
  - expose little implementation as possible
  - allows you to change hidden details later

Notes:

- try to avoid setters
- Organize program functionality around kinds of abstract objects
  - For each object kind, offer a specific set of operations on the objects
  - Objects are otherwise opaque: Details of representation are hidden
  - Messages to the receiving object
- Distinguish interface from class
  - Interface: expectations
  - Class: delivery on expectations (the implementation)
  - Anonymous class: special Java construct to create objects without explicit classes: Point x = new Point() /* implementation */ ;
- Explicitly represent the taxonomy of object types
  - This is the type hierarchy (!= inheritance, more on that later): A CartesianPoint is a Point
- Design Patterns!!
  - Design Patterns by Gamma,Helm,Johnson,Vlissides

sources:

- `http://www.cs.cmu.edu/~charlie/courses/15-214/2015-fall/index.html#schedule`

Design for Reuse

Delegation:

- Delegation is simply when one object relies on another object for some subset of its functonality
  - Sorter is delegating functonality to some Comparator implementation
- Judicious delegation enables code reuse
  - Sorter can be reused with arbitrary sort orders
  - Comparators can be reused with arbitrary client code that needs to compare integers

Delegation and design:

- Small interfaces
- Classes to encapsulate algorithms
  - ex: the Comparator, the Strategy pattern

Inheritance:

- Typical roles:
  - An interface defines expectations/commitment for clients
  - An abstract class is a convenient hybrid between an interface and a full implementation
  - A subclass overrides a method definition to specialize its implementation

Benefits of Inheritance:

- Reuse of code
- Modeling flexibility
- A Java aside:
  - Each class can directly extend only one parent class
  - A class can implement multiple interfaces

Power of object oriented interfaces:

- Subtype polymorphism
  - Different kinds of objects can be treated uniformly by client code
- e.g., a list of all accounts
  - Each object behaves according to its type
- If you add new kind of account, client code does not change

Inheritance and subtyping:

- Inheritance is for code reuse
  - Write code once and only once
  - Superclass features implicitly available in subclass
- Subtyping is for polymorphism
  - Accessing objects the same way, but getting different behavior
  - Subtype is substitutable for supertype

Java details: final:

- A final field: prevents reassignment to the field after initialization
- A final method: prevents overriding the method
- A final class: prevents extending the class
  - e.g., public final class CheckingAccountImpl

Type Casting:

- Sometimes you wan a different type than what you have
  - ex: float pi=3.14; int indianapi=(int) pi;
- Useful if you have more specific subtype
- Advice: avoid downcasting types

  - Never downcast within superclass to a subclass

Behavioral Subtyping:

- Compiler enforced rules in Java:
  - Subtype (subclass, subinterface, object implementing interface) can add but not remove methods
  - Overriding method must return same type or subtype
  - Overriding method must accept same parameter types
  - Overriding method may not throw additional exceptions
  - Concrete class must implement all undefined interface methods and abstract methods
- A subclass must fulfill all contracts its superclass does:
  - same or strong invariants
  - same or stronger post
  - conds for all methods
  - same or weaker pre
  - conds for all methods

Parametric polymorphism via java generics:

- Parametric polumorphism is the ability to define a type generically to allow static type
- checking with out fully specifying types
- The java.util.Stack instead
  - A stack of some type T:

```
public class Stack<T> {
   public void push(T obj){...}
   public T pop() { ...}
}
```

- Improves typechecking, simplifies client code

Notes:

- Template method design pattern
- Decorator design pattern

Design for Robustness

Exceptions:

- Notify caller of exceptional circumstance (usually operational failure)
- Semantics
  - An exception propagates up the function
  - call stack until main() is reached (terminates program) or until the exception is caught
- Sources of exceptions:
  - Program throwing an exception
  - Exception thrown by the Java Virtual Machine

Java: Finally:

The finally block always runs after try/catch

Design choice: checked and unchecked:

- Unchecked exception: any subclass of RuntimeException
  - Error which is highly unlikely and/or unrecoverable
- check exception: any subclass of Exception that is not a subclass of RuntimeException
  - Error that every caller should be aware of and explicitly decide to handle or pass on
- Return values(- 1, false, null): If failure is common and expected possibility

Creating and throwing your own exceptions:

- Methods must declare any checked exceptions they might throw
- If your class extends java.lang.Throwable you can throw it:
  -
```
if (some__){
  throw new customException("Blah blah");
 }
```

Benefits of exceptions:

- High level summary of error and stack trace
  - Compare: core dumped in C
- Can't forget to handle common failure modes
  - Compare: using a flag or special return value
- Can optionally recover from failure
  - Compare: calling System.exit()
- Improve code structure
  -
  - Separate routine operations from error
  - handling
- Allow consisten clean
- up in both normal and exceptional operation

Guide for exceptions:

- Catch and handle all checked exceptions
  - Unless there is no good way
- Use runtime exceptions for programming error
- Other
  - Don't catch an exception without (at least somewhat) handling the error
  - When you throw an exception describe the error
  - if you re
  - throw an exception, always include the original exception as the clause

Modular Protection:

- Errors and bugs unavoidable but exceptions should not leak across modules (methods, classes) if possible
- Good modules handles exceptional conditions locally

  - Local input validation and local exception handling where possible
  - Explicit interfaces with clear pre/post conditions
- Explicitly documented and checked exceptions where exceptional conditions may propagate between modules
  - Information hiding -encapsulation of critical code (likely bugs, likely exceptions)

Problems when testing (sub -)systems:

- User interfaces and user interactions
  - Users click buttons, interpret output
  - Waiting/timing issues
- Test data vs. real data
- Testing against big infrastructure (database, web services,..)
- Testing with side effects (e.g. printing and mailing documents)
- Nondeterministic behavior
- Concurrency

Testing strategies in environments:

- Separate business logic and data representation from GUI for testing
- Test algorithms locally without large environment using stubs
- Advantage of stubs
  - Create deterministic response
  - Can reliably simulate spurious states (network error)
  - Can speed up test execution
  - Can simulate functionality not yet implemented
- Automate

Scaffolding:

- Catch bugs early: Before client code or service available
- Limit scope of debugging: Localize errors

- Improve coverage
  - System level tests may only cover 70
  - Simulate unusual error conditions
- Validate internal interface/API designs
  - Simulate clients in advance of their developement
  - Simulate services in advance of their development
- Capture developer intent (in absence of specification documentation)
  - A test suite formally captures elements of design intent
  - Developer documentation
- Improve low
- level design
  - Early attention to ability to test

General

Criticism:

- target wrong problem
- lacks formal foundations
- leads to inefficient solutions
- does not differ significantly from other abstractions

Sources:

- `https://sourcemaking.com/design_patterns`
- `https://en.wikibooks.org/wiki/Computer_Science_Design_Patterns`
- `https://en.wikipedia.org/wiki/Software_design_pattern`

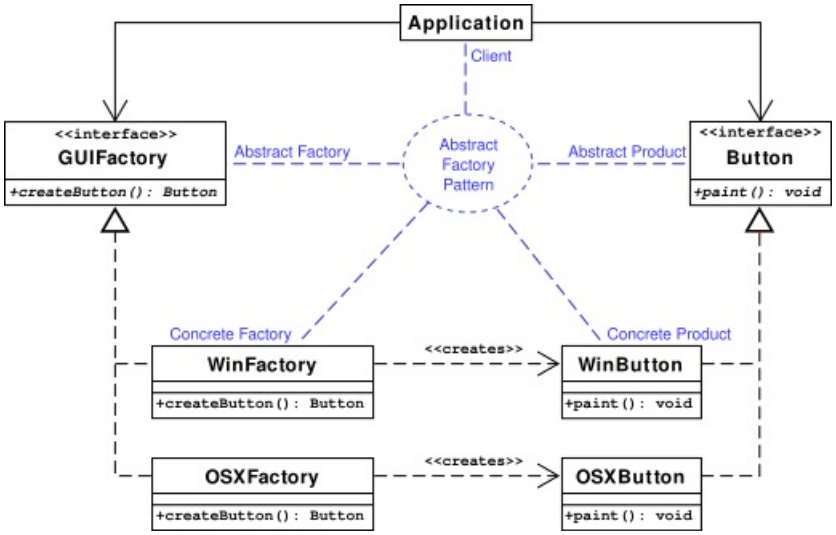
Creation

General:

- deal with object creation mechanisms, trying to create objects in a manner suitable to the situation
- These design patterns are all about class instantiation
- This pattern can be further divided into class
- creation patterns and object
- creational patterns
- While class
- creation patterns use inheritance effectively in the instantiation process, object
- creation patterns use delegation effectively to get the job done
- The creational patterns aim to separate a system from how its objects are created, composed, and represented
- They increase the system's flexibility in terms of the what, who, how, and when of object creation

Abstract Factory:

- Definition/Use
  - provides an interface for creating related or dependent objects without specifying the objects' concrete classes
  - provide an interface for creating families of related or dependent objects without specifying their concrete classes
  - encapsulates "new" ex: new product()
  - determines concrete type but returns abstract pointer
    - client code has no knowledge and isn't burdened by concrete type
    - adding new concrete types done by modifying client code to use different factory (1 line)
  - can determine concrete type from config file for example
- Structure



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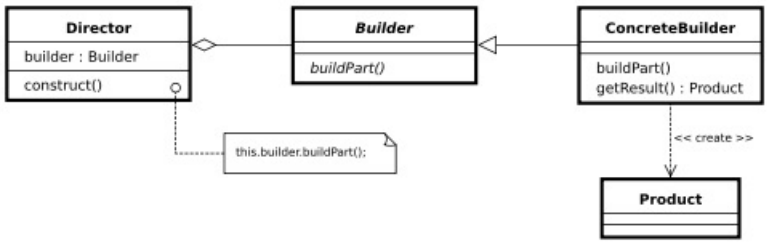
Builder:

- Definition/Use
  - separates the construction of a complex object from its representation so that the same construction process can create different representations
  - builder pattern is useful to avoid a huge list of constructors for a class
  - an application needs to create the elements of a complex aggregate
  - use builder to store parameters and then use that builder in constructor
  - separate the construction of a complex object from its representation so same construction can create different representations
- Structure



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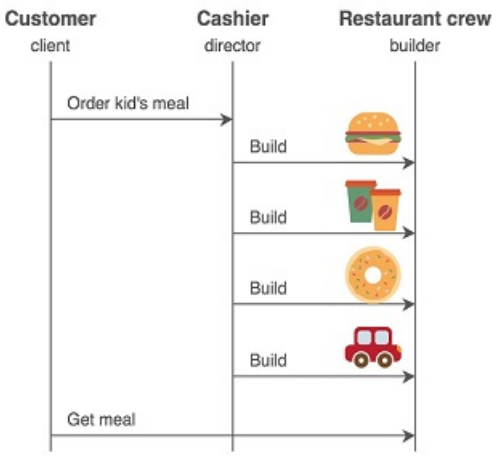
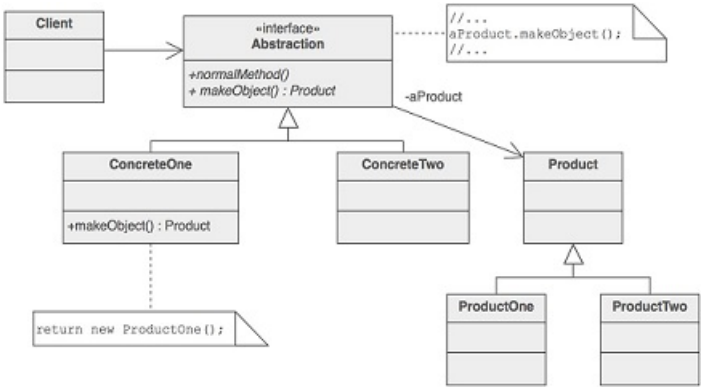


- Example
  - StringBuffer and StringBuilder
- Notes
  - put the builder term in the name of the builder class to indicate the use of the pattern to the other developers
  - if the target class contains flat data, your builder class can be constructed as a Composite that implements the Interpreter pattern

---

Factory Method:

- Definition/Use
  - allows a class to defer instantiation to subclasses
  - new operator considered harmful
  - define an interface for creating an object, but let subclasses decide which class to instantiate
  - provide a way for users to retrieve an instance with a known compile-time type, but whose runtime type may actually be different
  - an increasingly popular definition of factory method is: a static method of a class that returns an object of that class' type
    - unlike a constructor, the actual object it returns might be an instance of a subclass
- Structure



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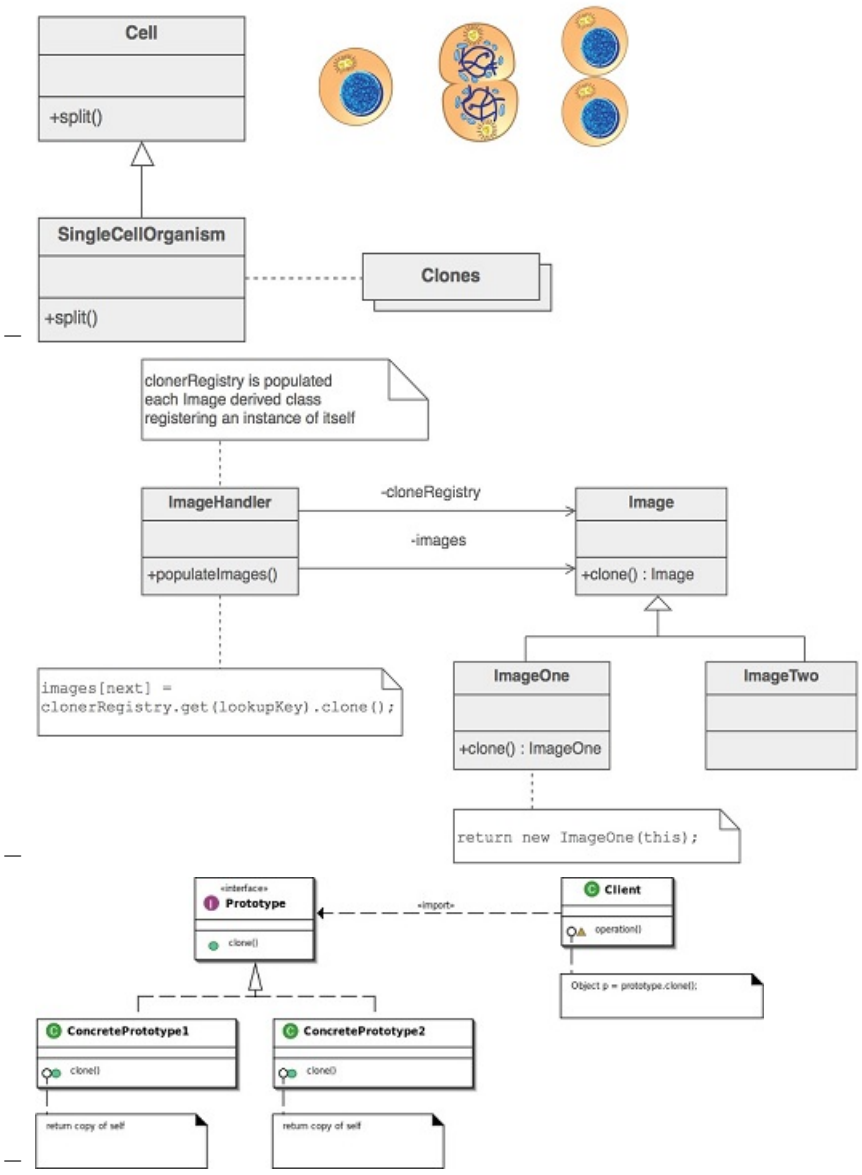
- Example
  - a factory method that is supposed to return an instance of the class Foo may return an instance of the class Foo, or an instance of the class Bar, so long as Bar inherits from Foo
  –
  ```
  Color.make_RGB_color(float red, float green, float blue)
  Color.make_HSB_color(float hue, float saturation, float brightness)
  ```
  –
  ```
  Letter.getLetter(char) if vowel return Vowel(char) else Consonant(char)
      (vowel, consonant extend letter)
  ```
- Notes
  - consider making all constructors private or protected

Prototype:

- Definition/Use
  - specifies the kind of object to create using a prototypical instance, and creates new objects by cloning this prototype
  - when the type of objects to create is determined by a prototypical instance, which is cloned to produce new objects
  - application ”hard wires” the class of object to create in each ”new” expression
- Structure



- Notes
  - add clone() method
  - add registry
  - put the prototype term in the name of the prototype classes to indicate the use of the pattern to the other developers

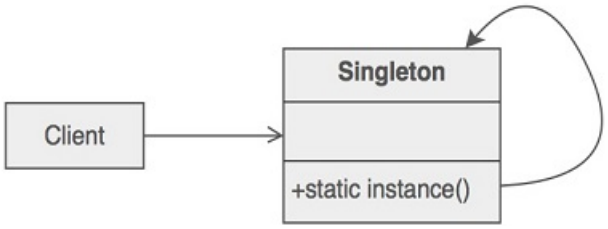
---

Singleton:

- Definition/Use
  - ensures that a class only has one instance, and provides a global point of access to it

  - ensure a class has only one instance, and provide a global point of access to it

- Structure

  - 

- Notes

  - make instantiation(private ThisSingleton()) private aka define all constructors to be protected or private
  - name the method getInstance() to indicate the use of the pattern to the other developers
  - define a private static attribute in the "single instance" class

---

Comparison:

- abstract Factory classes are often implemented with Factory Methods, but they can be implemented using Prototype
- factory method: creation through inheritance, prototype: creation through delegation

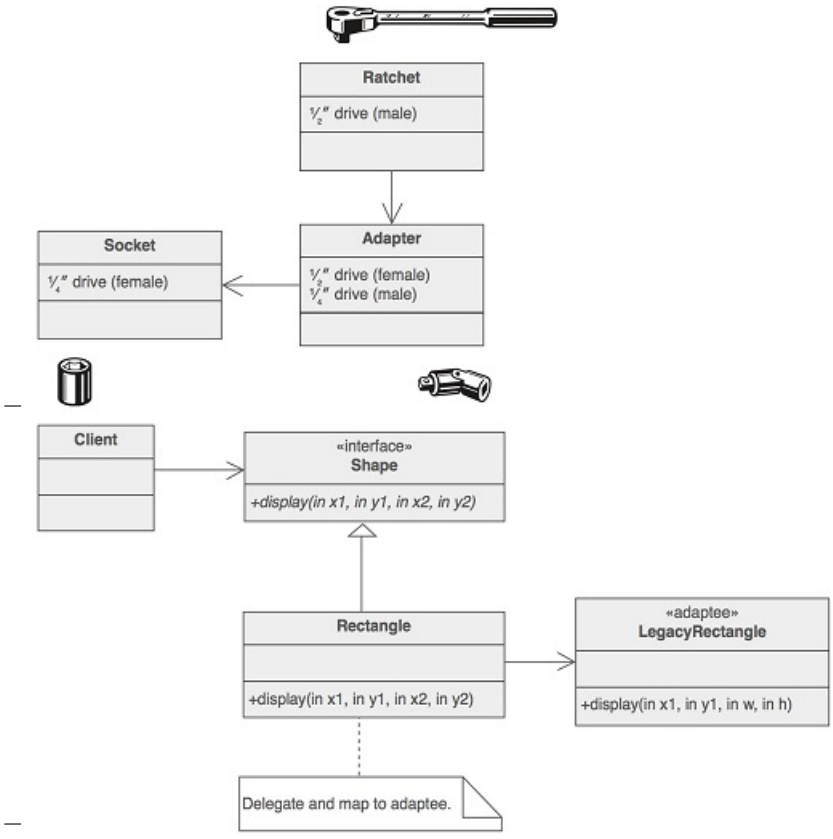
Structural

General:

- ease the design by identifying a simple way to realize relationships between entities
- about class and object composition
- use inheritance to compose interfaces
- define ways to compose objects to obtain new functionality

Adapter:

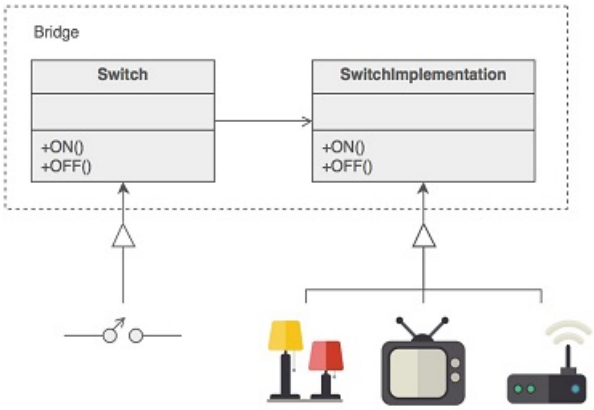
- Definition/Use
  - 'adapts' one interface for a class into one that a client expects
  - used when a client class has to call an incompatible provider class
  - an "off the shelf" component offers compelling functionality but its "view of the world" is not compatible
  - wrap an existing class with a new interface
- Structure



- Notes
  - put the adapter term in the name of the adapter class to indicate the use of the pattern to the other developers

---

Bridge:

- Definition/Use
  - decouple an abstraction from its implementation so that the two can vary independently
  - useful when a code often changes for an implementation as well as for a use of code
  - decouple an abstraction from its implementation so that the two can vary independently
- Structure
  - 

- Notes
  - design the separation of concerns: what does the client want, and what do the platforms provide

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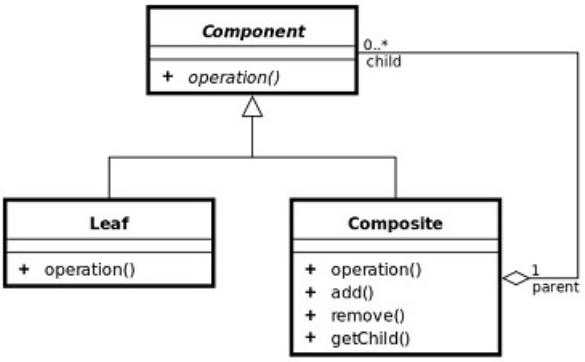
Composite:

- Definition/Use
  - a tree structure of objects where every object has the same interface
  - application needs to manipulate a hierarchical collection of "primitive"(leaf) and "composite" objects
- Structure



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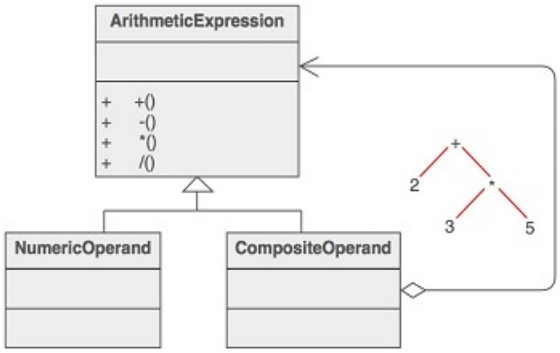

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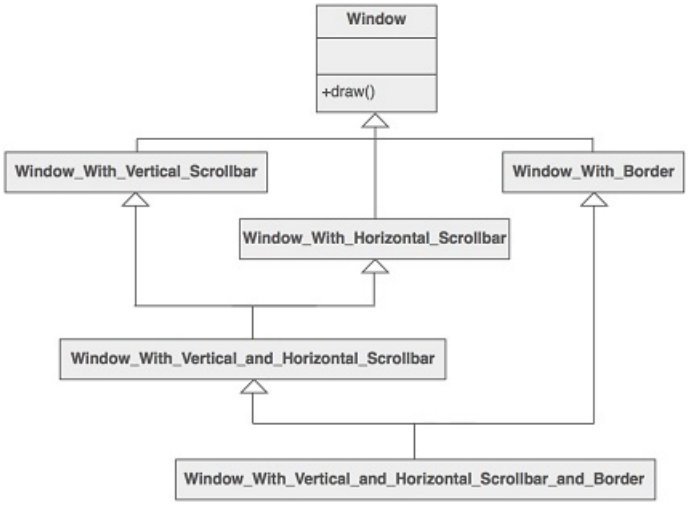
- Examples
  - GUI, widgets organized in a tree and operations (resize, repainting) on all widgets processed using pattern
- Notes
  - consider the heuristic, "containers that contain containees, each of which could be a container"

Decorator (Wrapper):

- Definition/Use
  - add additional functionality to a class at runtime where subclassing would result in an exponential rise of new classes
  - client-specified embellishment of a core object by recursively wrapping it
- Structure



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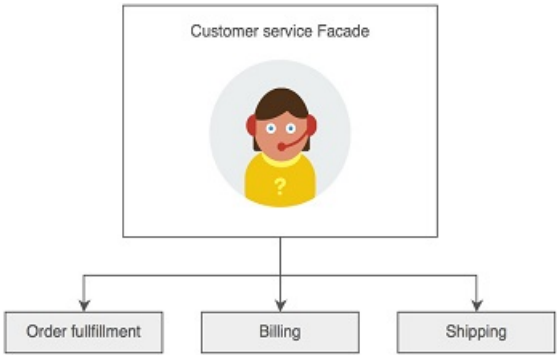
*
```
Widget* aWidget = new BorderDecorator(
  new HorizontalScrollBarDecorator(
    new VerticalScrollBarDecorator(
      new Window( 80, 24 ))));
aWidget->draw();
```

- Notes
  - ensure the context is: a single core (or non-optional) component, several optional embellishments or wrappers, and an interface that is common to all

---

Farcade:

- Definition/Use
  - create a simplified interface of an existing interface to ease usage for common tasks
  - hides the complexities of the system and provides an interface to the client from where the client can access the system
- Structure



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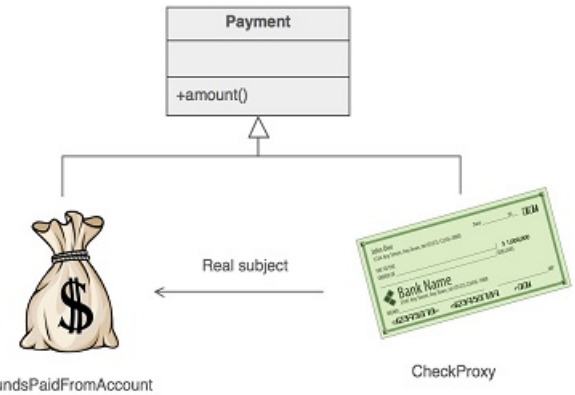
- Notes
  - often singletons because only one facade object is required
  - client uses (is coupled to) the facade only

Flyweight:

- Definition/Use
  - a large quantity of objects share a common properties object to save space
  - each "flyweight" object is divided into two pieces
    - the state-dependent (extrinsic) part: stored or computed by client objects, and passed to the Flyweight when its operations are invoked
    - the state-independent (intrinsic) part: stored (shared) in the Flyweight object
- Example
  - in video games, it is usual that you have to display the same sprite (i.e. an image of an item of the game) several times
    - it would highly use the CPU and the memory if each sprite was a different object
    - so the sprite is created once and then is rendered at different locations in the screen
    - this problem can be solved using the flyweight pattern
    - the object that renders the sprite is a flyweight

Proxy:

- Definition/Use
  - a class functioning as an interface to another thing
  - provide a surrogate or placeholder for another object to control access to it
- Structure



- Example
  - ProxyImage and RealImage

Comparison:

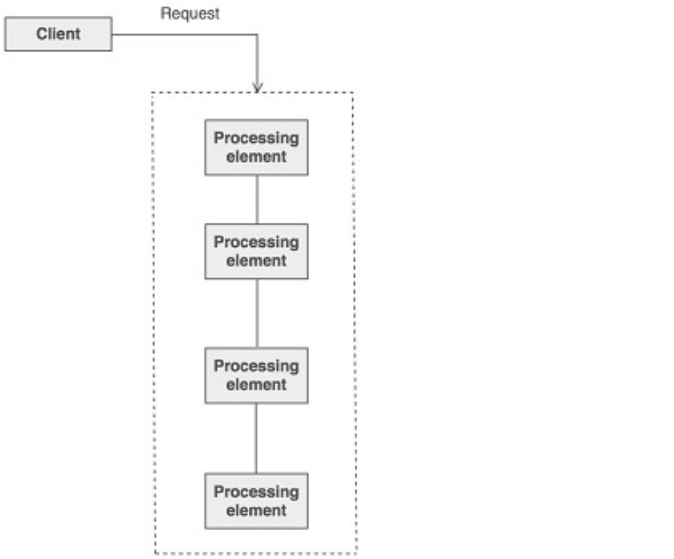
- adapter makes things work after they're designed, bridge makes them work before they are
- composite and decorator have similar structure diagrams, reflecting the fact that both rely on recursive composition to organize an open-ended number of objects
- decorator and proxy have different purposes but similar structures

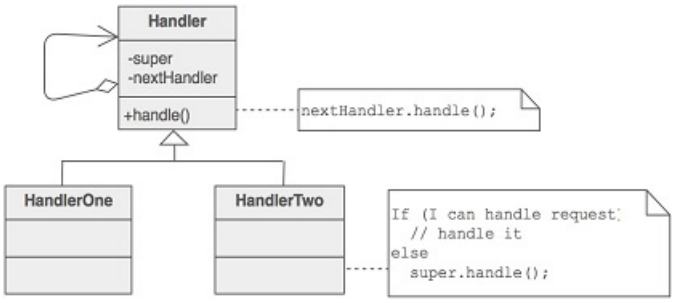
Behavioral

General:

Identify common communication patterns between objects and realize these patterns

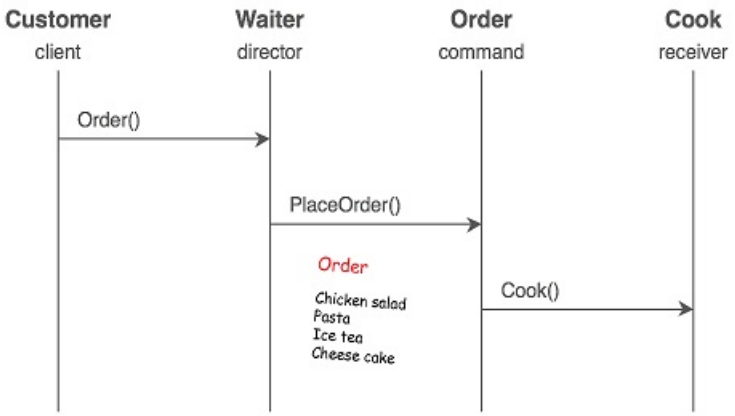
Chain of responsibility:

- Definition/Use
  - command objects are handled or passed on to other objects by logic-containing processing objects
  - avoid coupling the sender of a request to its receiver by giving more than one object a chance to handle the request
- Structure
  - 

  - 

- Notes
  - base class maintains a next pointer
  - if the request needs to be "passed on", then the derived class "calls back" to the base class, which delegates to the "next" pointer

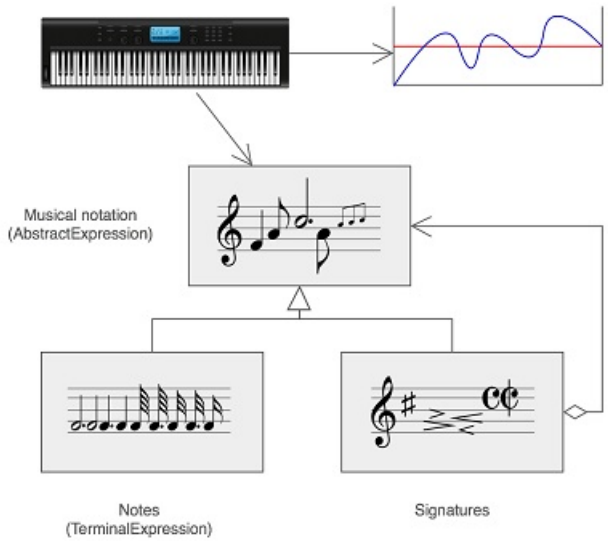
Command:

- Definition/Use
  - command objects encapsulate an action and its parameters
  - Need to issue requests to objects without knowing anything about the operation being requested or the receiver of the request
  - separation provides flexibility in the timing and sequencing of commands
  - command objects can be thought of as "tokens",created by one client that knows what need to be done, passed to another client that has the resources for doing it
- Structure
  - 

- Notes
  - define a Command interface with a method signature like execute()

Interpreter:

- Definition/Use
  - implement a specialized computer language to rapidly solve a specific set of problems
  - map a domain to a language, the language to a grammar, and the grammar to a hierarchical object
  - oriented design
- Structure



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- Notes
  - the pattern doesn't address parsing. When the grammar is very complex, other techniques (such as a parser) are more appropriate

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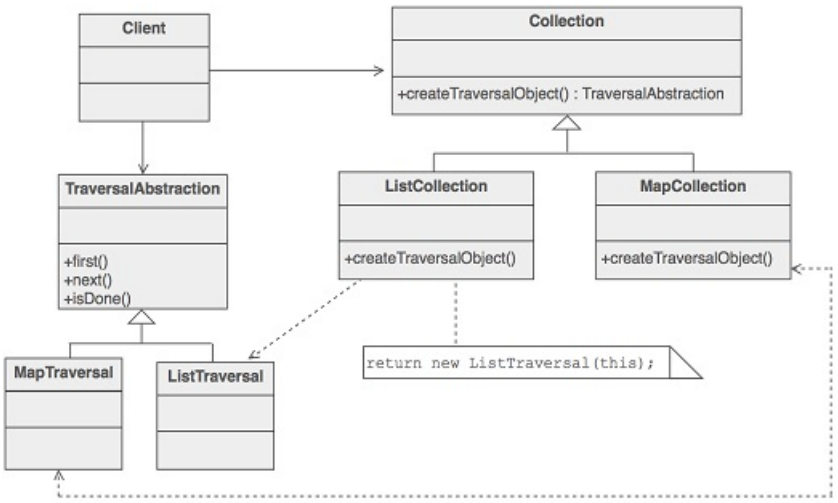
Iterator:

- Definition/Use
  - iterators are used to access the elements of an aggregate object sequentially without exposing its underlying representation
  - need to "abstract" the traversal of wildly different data structures so that algorithms can be defined that are capable of interfacing with each transparently
- Structure



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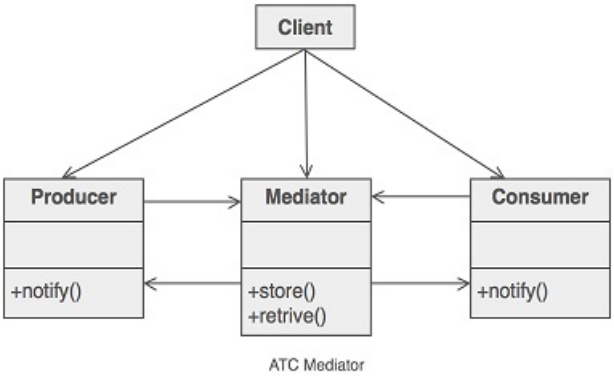
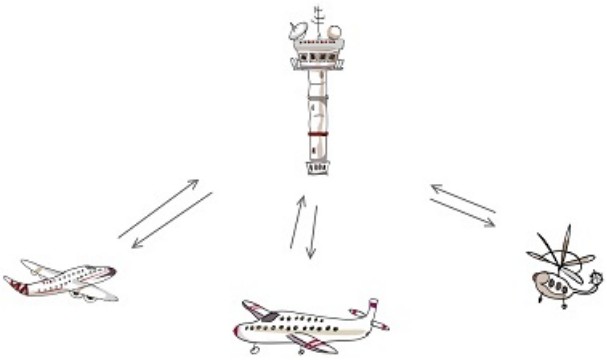
- Notes
  - ```
    clients use the first(), is_done(), next(), and current_item() protocol to
        access the elements of the collection class
    ```

Mediator:

- Definition/Use
  - provides a unified interface to a set of interfaces in a subsystem
  - promotes loose coupling by keeping objects from referring to each other explicitly
- Structure
  - 

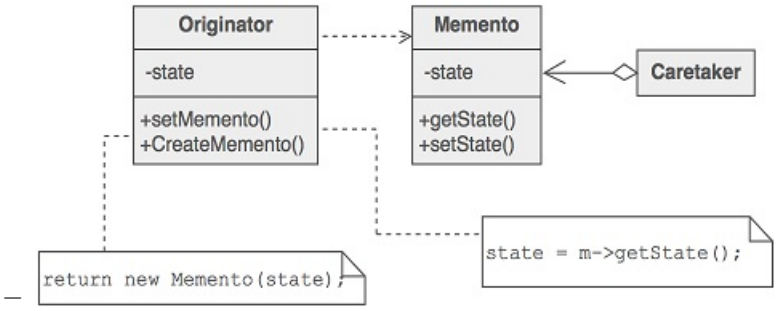
ATC Mediator
  - 
- Notes
  - be careful not to create a "controller" or "god" object

Memento:

- Definition/Use
    ```

  - provides the ability to restore an object to its previous state (rollback)
  - pattern defines three distinct roles
    * originator : the object that knows how to save itself
    * caretaker : the object that knows why and when the originator needs to save and restore itself
    * memento : the lock box that is written and read by the originator, and shepherded by the caretaker

- Structure



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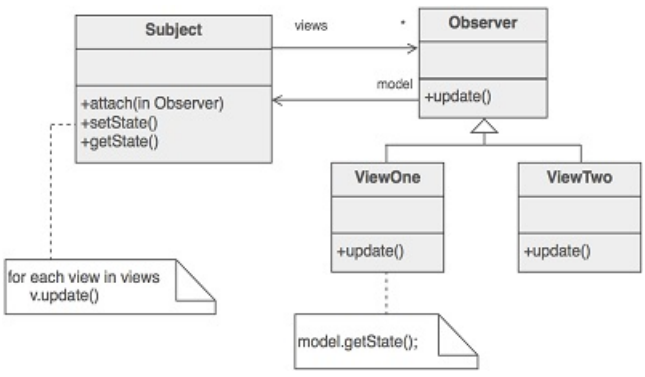
- Notes
  - identify the roles of caretaker and originator

Observer(Publish/Subscribe or Event Listener):

- Definition/Use
  - objects register to observe an event that may be raised by another object
  - defines a one
  - to
  - many relationship so that when one object changes state, the others are notified and updated automatically

- Structure



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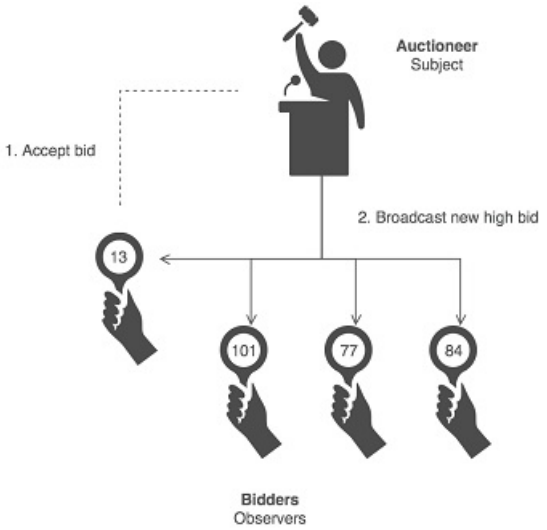

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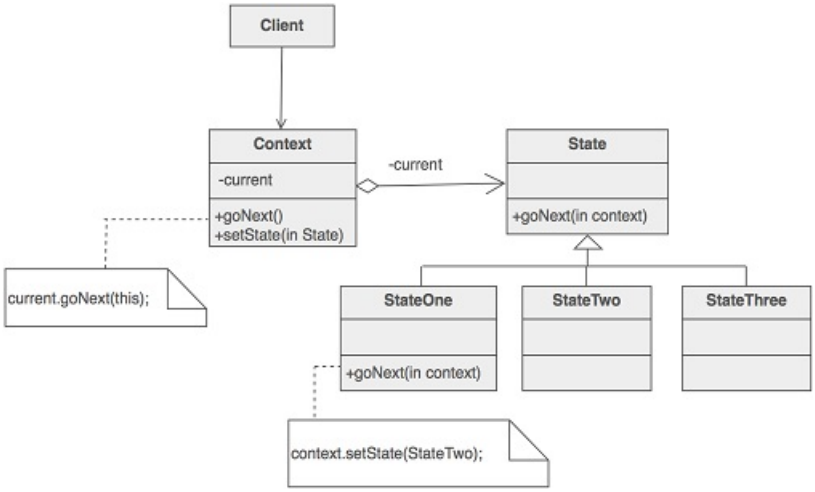
- Notes
  - subject broadcasts events to all registered observers

State:

- Definition/Use
  - a clean way for an object to partially change its type at runtime
  - a monolithic object's behavior is a function of its state
- Structure



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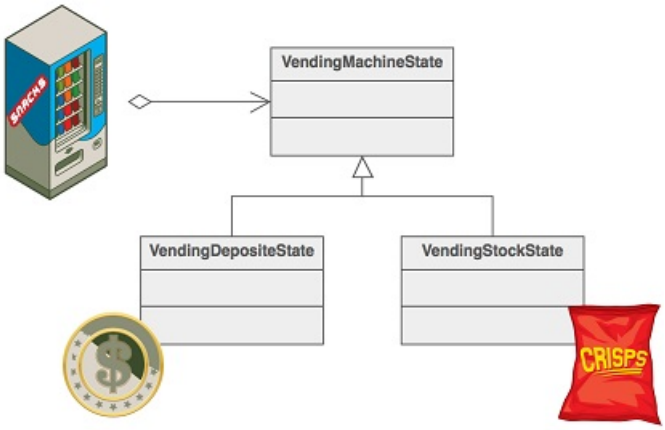

- Notes
  - pattern does not specify where the state transitions will be defined
    - the "context" object
    - each individual State derived class
      - advantage is ease of adding new State derived classes
      - disadvantage is each State derived class has knowledge of (coupling to) its siblings, which introduces dependencies between subclasses

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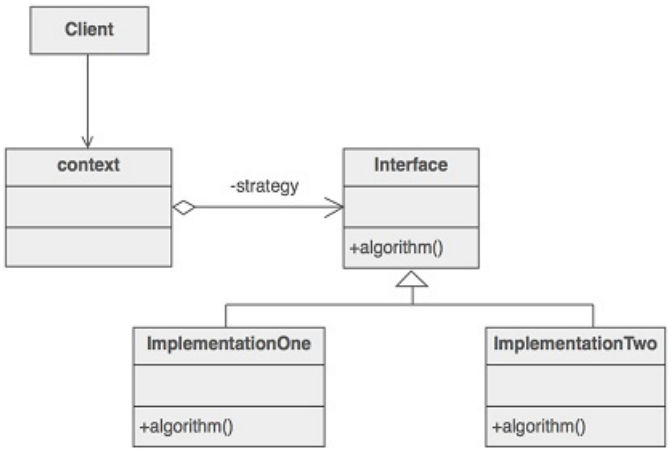
Strategy:

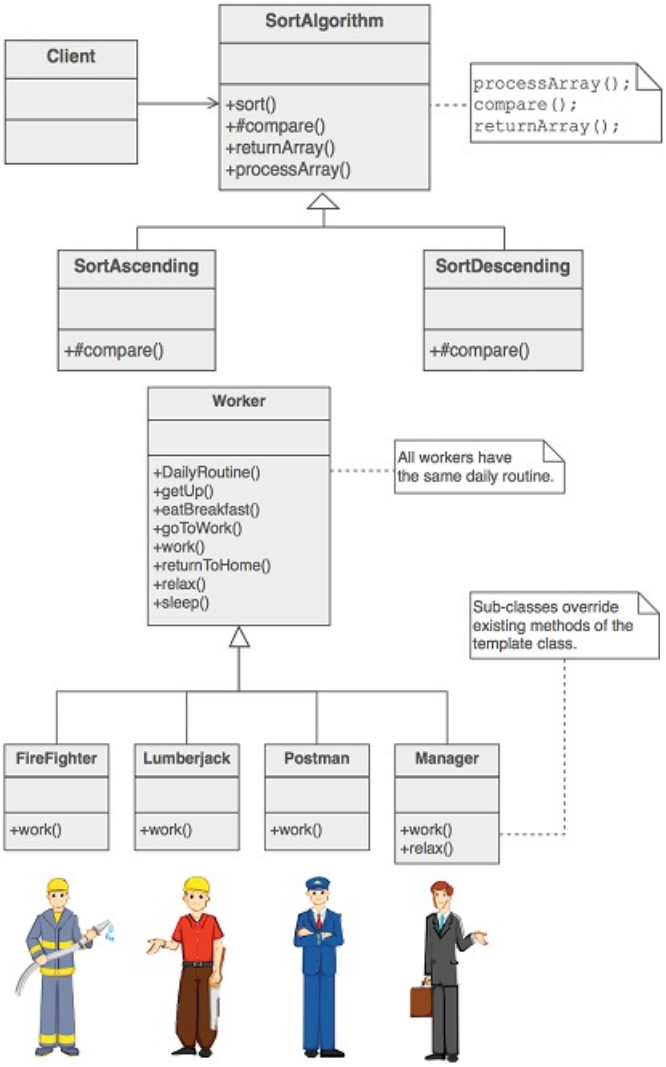
- Definition/Use
  - algorithms can be selected on the fly
  - defines a set of algorithms that can be used interchangeably
- Structure



- Notes

- identify an algorithm (i.e. a behavior) that the client would prefer to access through a "flex point"

Template method:

- Definition/Use
  - describes the program skeleton of a program
  - component designer decides which steps of an algorithm are invariant (or standard), and which are variant (or customizable)
- Structure
  -


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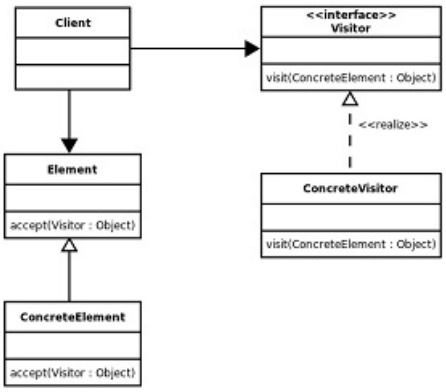
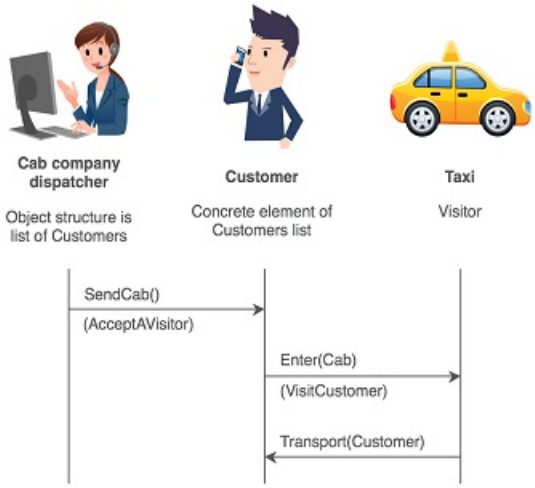
- Notes
  - examine the algorithm, and decide which steps are standard and which steps are peculiar to each of the current classes

Visitor:

- Definition/Use
  - a way to separate an algorithm from an object
- Structure
  - 

  - 

- Example
  - ```
    public interface CharacterVisitor {

      public void visit(char aChar);

    }

    public class MyString {

    // ... other methods, fields

      // Our main implementation of the visitor pattern
      public void foreach(CharacterVisitor aVisitor) {
    ```
    ```

```
    int length = this.length();
    // Loop over all the characters in the string
    for (int i = 0; i < length; i++) {
      // Get the current character, and let the visitor visit it.
      aVisitor.visit(this.getCharAt(i));
    }
  }

// ... other methods, fields

}// end class MyString

public class MyStringPrinter implements CharacterVisitor {

  // We have to implement this method because we're implementing the
      CharacterVisitor
  // interface
  public void visit(char aChar) {
    // All we're going to do is print the current character to the standard
        output
    System.out.print(aChar);
  }

  // This is the method you call when you want to print a string
  public void print(MyString aStr) {
    // we'll let the string determine how to get each character, and
    // we already defined what to do with each character in our
    // visit method.
    aStr.foreach(this);
  }

} // end class MyStringPrinter
```

- Notes
  - if you have and will always have only one visitor, you'd rather implement the composite pattern

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Comparison:

- chain of Responsibility, command, mediator, and observer, address how you can decouple senders and receivers, but with different trade
- offs
  - chain of Responsibility passes a sender request along a chain of potential receivers
- command and memento act as magic tokens to be passed around and invoked at a later time
  - in command, the token represents a request

- in memento, it represents the internal state of an object at a particular time
- polymorphism is important to command, but not to memento because its interface is so narrow that a memento can only be passed as a value