



Selected Design Patterns

Stéphane Ducasse
Stephane.Ducasse@univ-savoie.fr
<http://www.iam.unibe.ch/~ducasse/>

Goal

- What are patterns?
- Why?
- Patterns are not god on earth
- Example



Design Patterns

- Design patterns are **recurrent solutions** to design **problems**
- They are **names**
 - **Composite, Visitor, Observer...**
- They are **pros** and **cons**



From Architecture

Christoffer Alexander
"The Timeless Way of Building", Christoffer Alexander,
Oxford University Press, 1979, ISBN 0195024028

More advanced than what is used in computer science
only the simple parts got used.
pattern languages were skipped.



Why Patterns?

- Smart
 - Elegant solutions that a novice would not think of
- Generic
 - Independent on specific system type, language
- Well-proven**
 - Successfully tested in **several** systems
- Simple
 - Combine them for more complex solutions

There are really stupid patterns (supersuper) in some books so watch out!!!



Patterns provide...

- Reusable** solutions to **common** problems based on experiences from real systems
- Names** of abstractions above class and object level
 - a common vocabulary for developers
- Handling of functional and non-functional aspects
 - separating interfaces/implementation, loose coupling between parts, ...
- A basis for **frameworks** and toolkits
 - basic constructs to improve reuse
- Education and training support



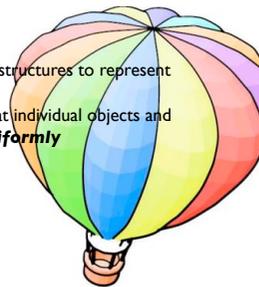
Elements in a Pattern

- Pattern name**
 - Increase of design vocabulary
- Problem** description
 - When to apply it, in what context to use it
- Solution** description (generic !)
 - The elements that make up the design, their relationships, responsibilities, and collaborations
- Consequences**
 - Results and trade-offs of applying the pattern



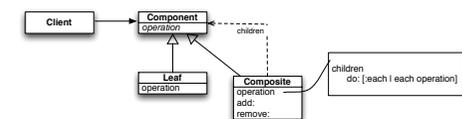
Composite

- Compose objects into tree structures to represent part-whole hierarchies.
- Composite lets **clients** treat individual objects and compositions of objects **uniformly**

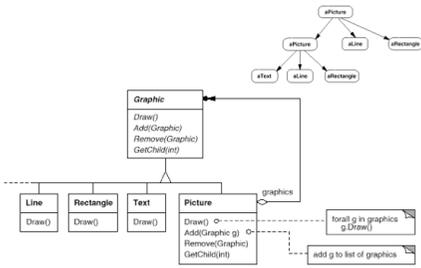


Composite Intent

Intent: Compose objects into tree structures to represent part-whole hierarchies. Composite lets clients treat individual objects and compositions of objects uniformly



Composite Pattern Motivation



S.Ducasse

10



Composite Pattern Applicability

Use the Composite Pattern when :

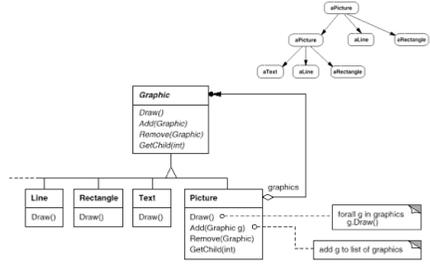
- you want to represent part-whole hierarchies of objects
- you want clients to be able to ignore the difference between compositions of objects and individual objects.
- Clients will treat all objects in the composite structure uniformly

S.Ducasse

11



Composite Pattern Possible Design



S.Ducasse

12



Composite Pattern Participants

- Component (Graphic)**
 - declares the interface for objects in the composition
 - implements default behavior for the interface common to all classes, as appropriate
 - declares an interface for accessing and managing its child components
- Leaf (Rectangle, Line, Text, ...)**
 - represents leaf objects in the composition. A leaf has no children
 - defines behavior for primitive objects in the composition

S.Ducasse

13



Composite Pattern

- Composite (Picture)**
 - defines behaviour for components having children
 - stores child components
 - implements child-related operations in the Component interface
- Client**
 - manipulates objects in the composition through the Component interface

S.Ducasse

14



Composite Pattern Collaborations

- Clients use the Component class interface to interact with objects in the composite structure.
- Leaves handle requests directly.
- Composites forward requests to its child components
- Consequences**
 - defines class hierarchies consisting of primitive and composite objects.
 - Makes the client simple. Composite and primitive objects are treated uniformly. (no cases)
 - Eases the creation of new kinds of components
 - Can make your design overly general

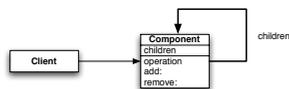
S.Ducasse

15



An Alternate Structure

Again structure is not intent!



S.Ducasse

16



Queries...

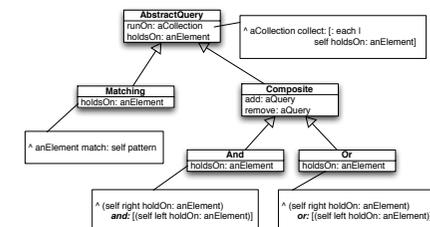
- To be able to specify different queries over a repository
- q1 := PropertyQuery property: #HNL with: #< value: 4.
- q2 := PropertyQuery property: #NOM with: #> value: 10.
- q3 := MatchName match: "figure"
- Compose these queries and treat composite queries as one query
- (e1 e2 e3 e4 ... en)((q1 and q2 and q4) or q3) -> (e2 e5)
- composer := AndComposeQuery with: (Array with: q1 with: q2 with: q3)

S.Ducasse

17



A Possible Solution



S.Ducasse

18



In Smalltalk

- Composite not only groups leaves but can also contain composites
- In Smalltalk add:, remove: do not need to be declared into Component but only on Composite. This way we avoid to have to define dummy behavior for Leaf

S.Ducasse



Composite Variations

- Use a Component superclass to define the interface and factor code there.
- Consider implementing abstract Composite and Leaf (in case of complex hierarchy)
- Only Composite delegates to children
- Composites can be nested
- Composite sets the parent back-pointer (add:/remove:)

S.Ducasse



Composite Variations

- Can Composite contain any type of child? (domain issues)
- Is the Composite's number of children limited?
- Forward
 - Simple forward. Send the message to all the children and merge the results without performing any other behavior
 - Selective forward. Conditionally forward to some children
 - Extended forward. Extra behavior
 - Override. Instead of delegating

S.Ducasse



Other Patterns

- Composite and Visitors
 - Visitors walks on structured objects
- Composite and Factories
 - Factories can create composite elements

S.Ducasse

22



Patterns...



S.Ducasse

23



Categories of Design Patterns

- Creational Patterns
 - Instantiation and configuration of classes and objects
- Structural Patterns
 - Usage of classes and objects in larger structures, separation of interfaces and implementation
- Behavioral Patterns
 - Algorithms and division of responsibility
- Concurrency
- Distribution
- Security

S.Ducasse

24



Some Creational Patterns

Abstract factory
Builder
Factory Method
Prototype
Singleton

S.Ducasse

25



Some Structural Patterns

Adapter
Bridge
Composite
Decorator
Façade
Flyweight
Proxy

S.Ducasse

26



Some Behavioral Patterns

Chain of responsibility
Command
Interpreter
Iterator
Mediator
Memento
Observer
State
Strategy
Template Method
Visitor

S.Ducasse

27



Alert!!! Patterns are invading

- Design Patterns may be a real **plague!**
- Do not apply them when you do not need them



- Design Patterns make the software more complex
 - More classes
 - More indirections, more messages
- Try to understand when **NOT** applying them!

S.Ducasse



About Pattern Implementation

This is **POSSIBLE** implementation not a definitive one

Do not confuse structure and intent!!!
Patterns are about **INTENT**
and **TRADEOFFS**



S.Ducasse

29



Singleton

Ensure that a class has only one instance, and provide a global point of access to it



S.Ducasse



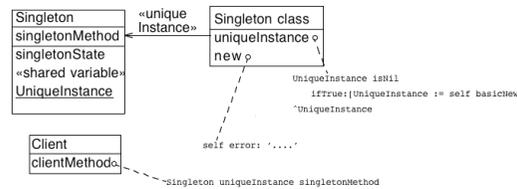
The Singleton Pattern

- **Intent:** Ensure that a class has only one instance, and provide a global point of access to it
- **Problem:** We want a class with a unique instance.
- **Solution:** We specialize the #new class method so that if one instance already exists this will be the only one. When the first instance is created, we store and return it as result of #new.

S.Ducasse



Singleton Possible Structure



S.Ducasse



The Singleton Pattern

```
[aLan]
aLan := NetworkManager new
aLan == LAN new -> true
aLan uniqueInstance == NetworkManager new -> true
```

```
NetWorkManager class
instanceVariableNames: 'uniqueInstance'
```

```
NetworkManager class>>new
self error: 'should use uniqueInstance'
```

```
NetworkManager class>>uniqueInstance
uniqueInstance isNil
if True: [ uniqueInstance := self basicNew initialize].
^uniqueInstance
```

S.Ducasse



The Singleton Pattern

- Providing access to the unique instance is not always necessary.
- It depends on what we want to express. The difference between #new and #uniqueInstance is that #new potentially initializes a new instance, while #uniqueInstance only returns the unique instance (there is no initialization)
- Do we want to communicate that the class has a singleton? **new?** **defaultInstance?** **uniqueInstance?**

S.Ducasse



Implementation Issues

- Singletons may be accessed via a global variable (ex: NotificationManager uniqueInstance notifier).


```
SessionModel>>startupWindowSystem
"Private - Perform OS window system startup"
Notifier initializeWindowHandles.
...
oldWindows := Notifier windows.
Notifier initialize.
...
^oldWindows
```
- Global Variable or Class Method Access
 - Global Variable Access is dangerous: if we reassign Notifier we lose all references to the current window.
 - Class Method Access is better because it provides a single access point. This class is responsible for the singleton instance (creation, initialization,...).

S.Ducasse



Implementation Issues

Persistent Singleton: only one instance exists and its identity does not change (ex: NotifierManager in Visual Smalltalk)

Transient Singleton: only one instance exists at any time, but that instance changes (ex: SessionModel in Visual Smalltalk, SourceFileManager, Screen in VisualWorks)

Single Active Instance Singleton: a single instance is active at any point in time, but other dormant instances may also exist. Project in VisualWorks

S.Ducasse

36



Implementation Issues

classVariable or class instance variable
classVariable
One singleton for a complete hierarchy
Class instance variable
One singleton per class

S.Ducasse

37



Access?

In Smalltalk we cannot prevent a client to send a message (protected in C++). To prevent additional creation we can redefine new/new:

```
Object subclass: #Singleton
instanceVariableNames: 'uniqueInstance'
classVariableNames: ''
poolDictionaries: ''
```

```
Singleton class>>new
self error: 'Class ', self name, ' cannot create new instances'
```

S.Ducasse

38



Access using new: not good idea

```
Singleton class>>new
^self uniqueInstance
```

The intent (uniqueness) is not clear anymore! New is normally used to return newly created instances. The programmer does not expect this:

```
|screen1 screen2|
screen1 := Screen new.
screen2 := Screen uniqueInstance
```

S.Ducasse

39



Favor Instance Behavior

When a class should only have one instance, it could be tempting to define all its behavior at the class level. But this is not good:

Class behavior represents behavior of classes: "Ordinary objects are used to model the real world. MetaObjects describe these ordinary objects"

Do not mess up this separation and do not mix domain objects with metaconcerns.

What's happens if later on an object can have multiple instances? You have to change a lot of client code!

S.Ducasse

40



Time and not Scope

Singleton is about **time** not **access**

time: only one instance is available at the same time

access: can't you add an instance to refer to the object?

Singleton for access are as bad as global variables

Often we can avoid singleton by passing/referring to the object instead of favoring a global access point

It is worth to have one extra instance variable that refers to the right object

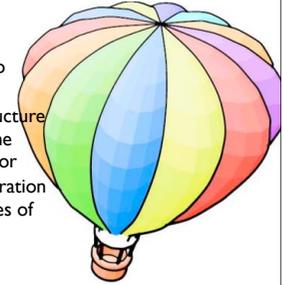
S.Ducasse

41



Visitor

Represent an operation to be performed on the elements of an object structure in a class separate from the elements themselves. Visitor lets you define a new operation *without* changing the classes of the elements on which it operates.



S.Ducasse

42



Visitor Intent

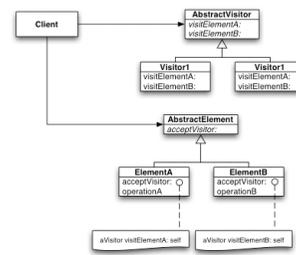
Intent: Represent an operation to be performed on the elements of an object structure in a class separate from the elements themselves. Visitor lets you define a new operation *without* changing the classes of the elements on which it operates.

S.Ducasse

43



Visitor Possible Structure



S.Ducasse

44



When to use a Visitor

Whenever you have a number of items on which you have to perform a number of actions, and When you 'decouple' the actions from the items.

Examples:

the parse tree (ProgramNode) uses a visitor for the compilation (emitting code on CodeStream)
GraphicsContext is a visitor for VisualComponents, Geometrics, and some other ones (CharacterArray, ...) Rendering documents

S.Ducasse

45



Applying the Visitor

So all our problems are solved, no?
Well...
when to use a visitor
control over item traversal
choosing the granularity of visitor methods
implementation tricks

S.Ducasse

46



When to Use a Visitor

Use a Visitor:
when the operations on items change a lot.
Do not use a visitor:
when the items you want to visit change a lot.
Question: But how do we know what to choose up-front?

S.Ducasse

47



Visitor Toy Example

Language to deal with arithmetic expressions.
It supports one kind of number, and has +, *, (,)
We want to evaluate expressions, and print them.

Example:

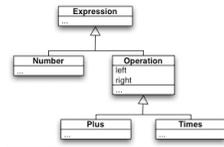
1 + 1
result: 1 + 1 = 2
((4 * 2) * (3 + 5)) * 3
result: (4 * 2 * (3 + 5)) * 3 = 192
...

S.Ducasse

48



Visitor Toy Example: ParseTree



S.Ducasse

49



Implementing the Actions

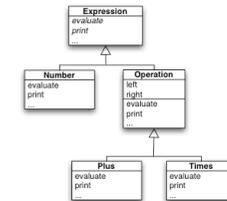
Two solutions:
add methods for evaluating, printing, ... on Expression and its subclasses
create a Visitor, add the visit methods on Expression and its subclasses, and implement visitors for evaluation, printing, ...

S.Ducasse

50



Visitor Toy Example Solution 1

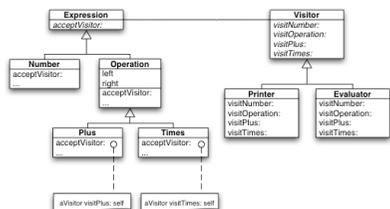


S.Ducasse

51



Visitor Toy Example 2



S.Ducasse

52



Toy Example: Discussion

So which solution to take?
In this case you might say:
printing is not easy
adding it directly on Expression clutters Expression (need to add instance variables etc.)
therefore we can factor out the printing on a separate class.
if we do this with a visitor we can then implement evaluation there as well.

S.Ducasse

53



Smalltalk's class extensions

Smalltalk has class extensions:
method addition
method replacement

So 'Decoupling' actions from items can be done:
e.g., put all the printing methods together.
take care: works only for methods
makes it also really easy to package a visitor!

Note: this is a static solution!

S.Ducasse

54

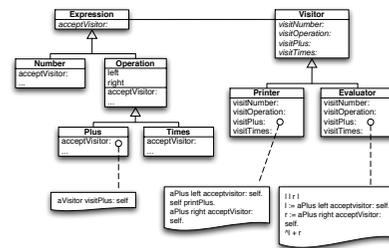


Controlling the traversal

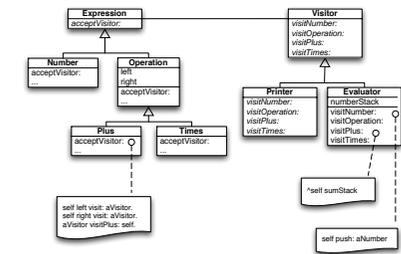
Somewhere in the visitor, items are traversed.
 Different places where the traversal can be implemented:
 in the visitor
 on the items hierarchy



Traversal on the Visitor



Traversal on the Items



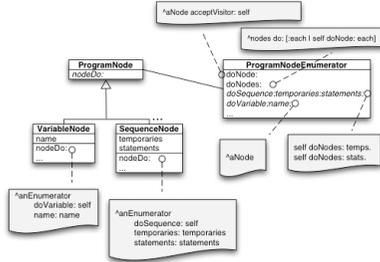
Granularity of Visit Methods

Sometimes you can pass context information with the visit methods
 So visitors have more information for implementing their operations



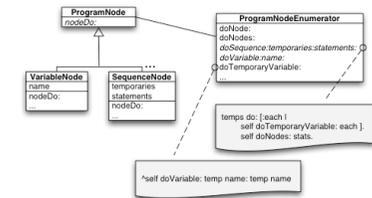
Granularity of Visit Methods

Regular case: nothing special is going on



Refined Granularity

Here methods allow finer control of variables (#doTemporaryVariable)

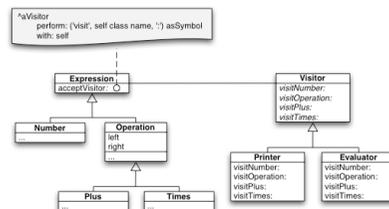


Implementation Tricks

You can implement it as we have shown before.
 But notice the general structure of the methods!
 This can be taken as advantage:
 code can be generated for a visitor:
 the method can be performed/invoked
 But take care:
 only works when there is a full correspondence.
 can make the code hard to understand.



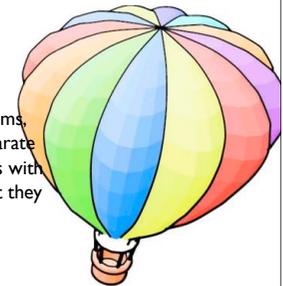
Using #perform:



Strategy

Define a family of algorithms,
 encapsulate each in a separate
 class and define each class with
 the same interface so that they
 can be interchangeable.

Also Know as Policy



Strategy Intent

- Define a family of algorithms, encapsulate each in a separate class and define each class with the same interface so that they can be interchangeable.



Motivation

Many algorithms exist for breaking a stream into lines.
Hardwiring them into the classes that requires them has the following problems:

- Clients get more complex
- Different algorithms can be used at different times
- Difficult to add new algorithms at run-time



Code Smells

```
Composition>>repair
formatting == #Simple
if True: [ self formatWithSimpleAlgo]
if False: [ formatting == #Tex
            if True: [self formatWithTex]
            ....]
```



Alternative

```
Composition>>repair
| selector |
selector := ('formatWith, formatting) asSymbol.
self perform: selector
```

Still your class gets complex...

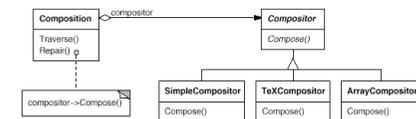


Inheritance?

- May not be the solution since:
- you have to create objects of the right class
 - it is difficult to change the policy at run-time
 - you can get an explosion of classes bloated with the use of a functionality and the functionalities.
 - no clear identification of responsibility



Strategy Solution

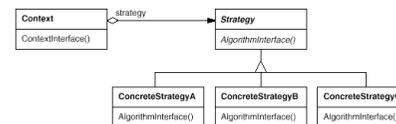


When

Many related classes differ only in their behavior
You have variants of an algorithm (space/time)
An algorithm uses data that the clients does not have to know



Structure



```
Composition>>repair
formatter format: self
```



Participants

Strategy (Compositor)
declares an interface common to all concrete strategies

Concrete Strategies
implement algorithm

Context
configure with concrete strategy
maintains a reference to the concrete strategy
may define an interface to let the strategy access data



Collaborations (i)

Strategy and Context interact to implement the chosen algorithm.

A context may pass all data required by the algorithm to the strategy when the algorithm is called

```
GraphVisualizer>>graphIt
....
grapher plot: data using: graphPane pen
```

```
Grapher>>plot: data using: aPen
```



Context passes itself as argument

Also know as self-delegation...

```
GraphVisualizer>>graphIt
grapher plotFor: self
```

```
BartChartGrapher>>plotFor: aGraphVisualizer
|data|
data := aGraphVisualizer data
....
```



BackPointer

```
Grapher class>>for: aGraphVisualizer
^ self new graphVisualizer: aGraphVisualizer
```

```
BartChartGrapher>>plot
...
graphVisualizer data..
graphVisualizer pen
```

Grapher (Strategy) points directly to GraphVisualizer (Context), so sharing strategy between different context may be difficult, if sharing is needed then use self-delegation



Collaboration (ii)

"A context forwards requests from its clients to its strategy. Clients usually create and pass a ConcreteStrategy object to the context; thereafter, clients interact with the context exclusively." GOF

Not sure that the client has to choose...



Consequences

- Define a family of pluggable algorithms
- Eliminates conditional statements
- Clients can choose between several implementations
- Clients must be aware of the different strategies
- Increase the number of objects
- Communication overhead between client and strategies
- Weaken encapsulation of the client



Domain-Specific Objects as Strategies

Strategies do not have to be limited to one single algorithm
They may represent domain specific knowledge

```
Mortgage
FixedRateMortgage
OneYear..
```



Known Uses

ImageRenderer in VW: "a technique to render an image using a limited palette"

```
ImageRenderer
NearestPaint
OrderedDither
ErrorDiffusion
```

View-Controller

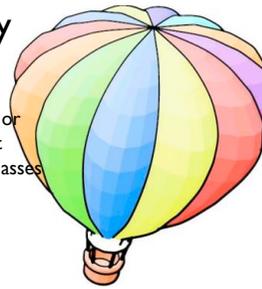
a view instance uses a controller object to handle and respond to user input via mouse or keyboard.
Controllers can be changed at run-time



Abstract Factory

Provide an interface for creating families of related or dependent objects without specifying their concrete classes

Also known as: Kit



Abstract Factory Intent

- Provide an interface for creating families of related or dependent objects without specifying their concrete classes



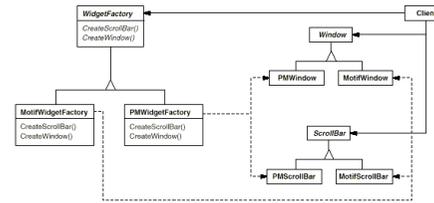
Abstract Factory Motivation

You have an application with different looks and feels. How to avoid to hardcode all the specific widget classes into the code so that you can change from Motifs to MacOSX?



Abstract Factory Motivation

Abstract factory introduce an interface for creating each basic kind of widget



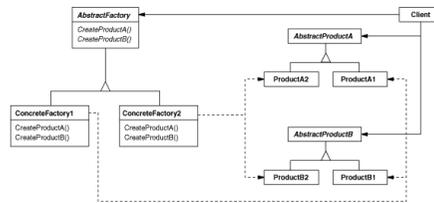
Abstract Factory Applicability

a system should be independent of how its products are created, composed, and represented a system should be configured with one of multiple families of products

a family of related product objects is designed to be used together, and you need to enforce this constraint you want to provide a class library of products, and you want to reveal just their interfaces, not their implementations



Abstract Factory Structure



Abstract Factory Participants

AbstractFactory (WidgetFactory) declares an interface for operations that create abstract product objects

ConcreteFactory (MotifWidgetFactory, PMWidgetFactory) implements the operations to create concrete product objects



Abstract Factory Participants

AbstractProduct (Window, ScrollBar) defines a product object to be created by the corresponding concrete factory implements the AbstractProduct interface

Client uses only interfaces declared by AbstractFactory and AbstractProduct classes



Implementation: Specifying the Factory

```
MazeGame class>>createMazeFactory
^ (MazeFactory new
  addPart:Wall named:#wall;
  addPart:Room named:#room;
  addPart:Door named:#door;
  yourself)
```

```
EnchantedMazeGame class>>createMazeFactory
^ (MazeFactory new
  addPart:Wall named:#wall;
  addPart:EnchantedRoom named:#room;
  addPart:DoorNeedingSpell named:#door;
  yourself)
```



SingleFactory

```
MazeGame class>>createMazeFactory
^ (MazeFactory new
  addPart:Wall named:#wall;
  addPart:Room named:#room;
  addPart:Door named:#door;
  yourself)
```

```
MazeGame class>>createEnchantedMazeFactory
^ (MazeFactory new
  addPart:Wall named:#wall;
  addPart:EnchantedRoom named:#room;
  addPart:DoorNeedingSpell named:#door;
  yourself)
```



Implementation: Using the Factory

```
MazeFactory>>createMaze:aFactory
| room1 room2 aDoor |
room1 := (aFactory make:#room) number: 1.
room2 := (aFactory make:#room) number: 2.
aDoor := (aFactory make:#door) from: room1 to: room2.
room1 atSide:#north put: (aFactory make:#wall).
room1 atSide:#east put: aDoor.
...
room2 atSide:#south put: (aFactory make:#wall).
room2 atSide:#west put: aDoor.
^ Maze new addRoom: room1; addRoom: room2; yourself
MazeFactory>>make: partName
^ (partCatalog at: partName) new
```



Abstract Factory Collaborations

Collaborations

Normally a single instance of ConcreteFactory is created at run-time
AbstractFactory defers creation of product objects to its ConcreteFactory subclass



Consequences

It isolates concrete classes
It makes exchanging product families easy
It promotes consistency among products
Supporting new kinds of products is difficult (set of products is somehow fixed)
The class factory "controls" what is created



Using Prototypes

The concrete factory stores the prototypes to be cloned in a dictionary called partCatalog.

```
make: partName  
  ^ (partCatalog at: partName) copy
```

The concrete factory has a method for adding parts to the catalog.

```
addPart: partTemplate named: partName  
  partCatalog at: partName put: partTemplate
```

Prototypes are added to the factory by identifying them with a symbol:



In Relations

Builder and Abstract Factory are closely related
But Builder is in charge of **assembling** parts
AbstractFactory is responsible of producing parts that work together



Known Uses

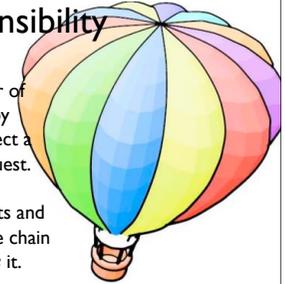
VisualWorks UILookPolicy



Chain of Responsibility

Avoid coupling the sender of a request to its receiver by giving more than one object a chance to handle the request.

Chain the receiving objects and pass the request along the chain **until** an object **handles** it.



Chain of Responsibility

Avoid coupling the sender of a request to its receiver by giving more than one object a chance to handle the request.

Chain the receiving objects and pass the request along the chain **until** an object **handles** it.



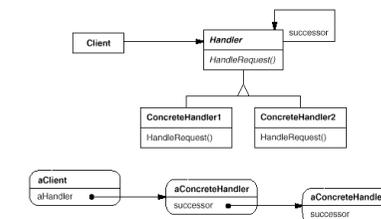
Motivation

The problem here is that the object that ultimately provides the help isn't known explicitly to the object (e.g., the button) that initiates the help request.

How to decouple senders and receivers?
By giving multiple objects a chance to handle a request.
The request gets passed along a chain of objects until one of them handles it.



Chain of Resp. Possible Structure



Participants

Handler

defines an interface for handling requests
may implement the successor link

ConcreteHandler

handles requests it is responsible for
can access its successor

Client

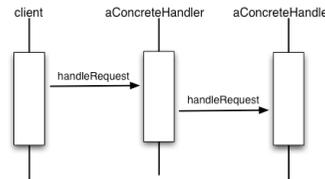
initiates the request to a concreteHandler



Dynamic

The first object in the chain receives the request and either handles it or forwards it to the next candidate on the chain, which does likewise.

The object that made the request has no explicit knowledge of who will handle it



Chain

Can be a linked list
But also a tree (cf. Composite Pattern)

Usually order can represent
specific to more general
priority: more important (security... in SmallWiki)



Consequences (i)

Reduced coupling. The pattern frees an object from knowing which other object handles a request.

An object only has to know that a request will be handled "appropriately."

Both the receiver and the sender have no explicit knowledge of each other, and an object in the chain doesn't have to know about the chain's structure.

Simplify object interconnections. Instead of objects maintaining references to all candidate receivers, they keep a single reference to their successor



Consequences (II)

Added flexibility in assigning responsibilities to objects.

flexibility in distributing responsibilities among objects.
can add or change responsibilities for handling a request by adding to or otherwise changing the chain at run-time.

Receipt isn't guaranteed.

no guarantee it'll be handled: the request can fall off the end of the chain without ever being handled.

A request can also go unhandled when the chain is not configured properly.



Differences with Decorator

A Decorator usually wraps the decorated object: clients point to the decorator and not the object

A Decorator does not have to forward the same message

A decorated object does not have to know that it is wrapped

With a chain of responsibility, the client asks the first chain objects explicitly.



Variations

Do the work or pass? or both?

the DP says that the handler either does the work or passes it to its successor but it can also do part of the job (see OO recursion)



OO Recursion: Hash, = and copy

```
Person>>= aPerson
  ^ self name = aPerson name
```

```
PersonName>>= aPersonName
  ^ (self firstName = aPersonName firstName)
  and: [(self lastName = aPersonName lastName)]
```

```
String>>= aString
  ...
```



OO Recursion: Hash, = and copy

```
Person>>hash
  ^ self name hash
```

```
PersonName>>hash
  ^ self firstName hash bitXor: self lastName hash
```



OO Recursion

With Chain of Responsibility you may recur from leave to root, from most specific to more general.
Default in root, specific and recursion in leaves

With OO recursion, from composite (person) to components (leaves)
Default in leave (String =)



Smalltalk Specific

Automatic Forwarding with doesNotUnderstand:
can work
but can be dangerous



Wrap-up

Patterns are names

Patterns are about tradeoffs
Know when not to apply them

