Selected Design Patterns

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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 !)

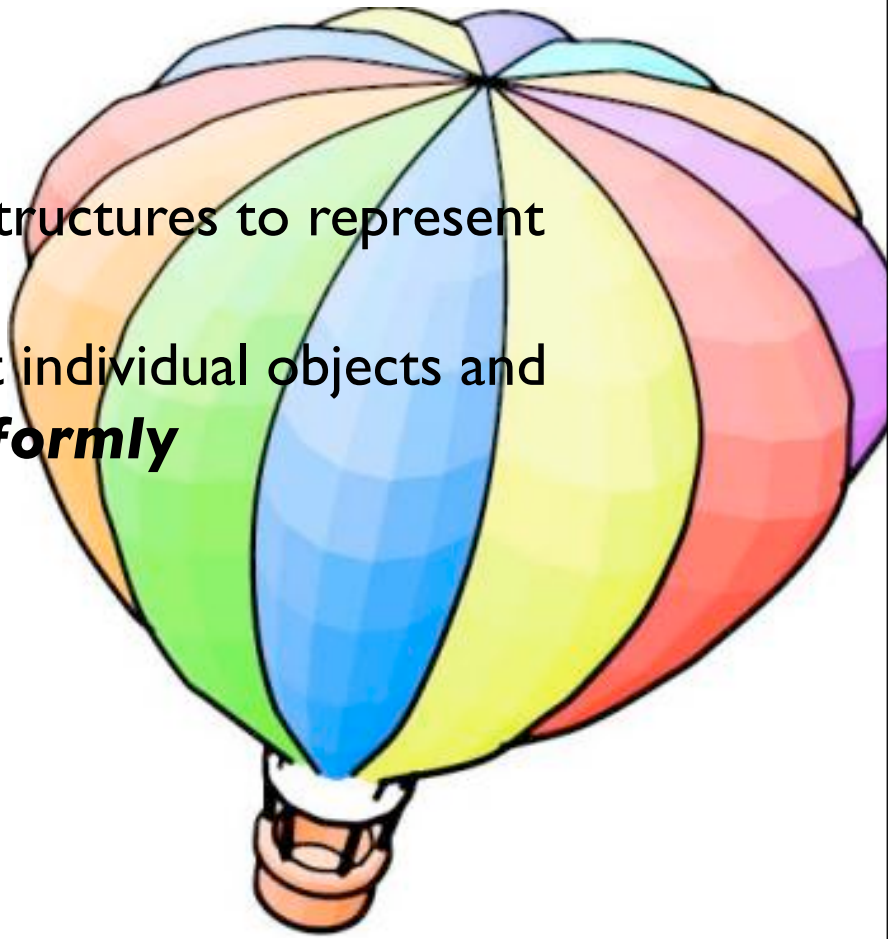
The elements that make up the design, their relationships, responsibilities, and collaborations

Consequences

Results and trade-offs of applying the pattern

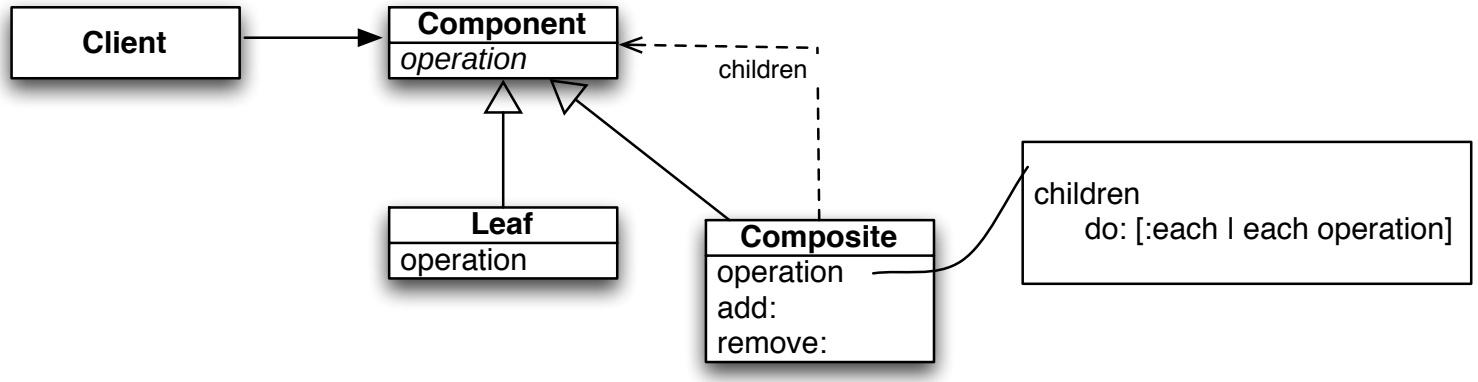
Composite

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

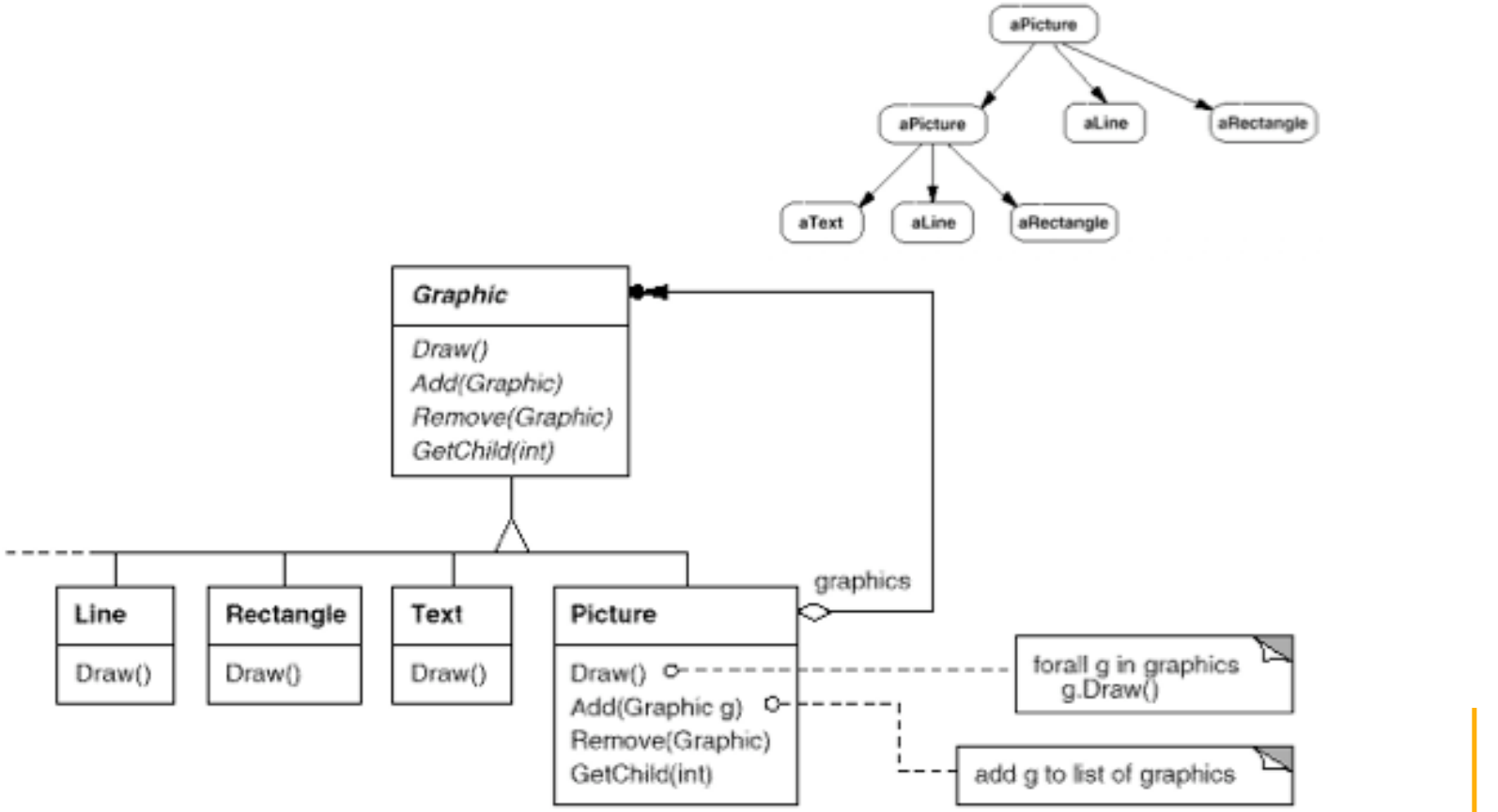


Composite Intent

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

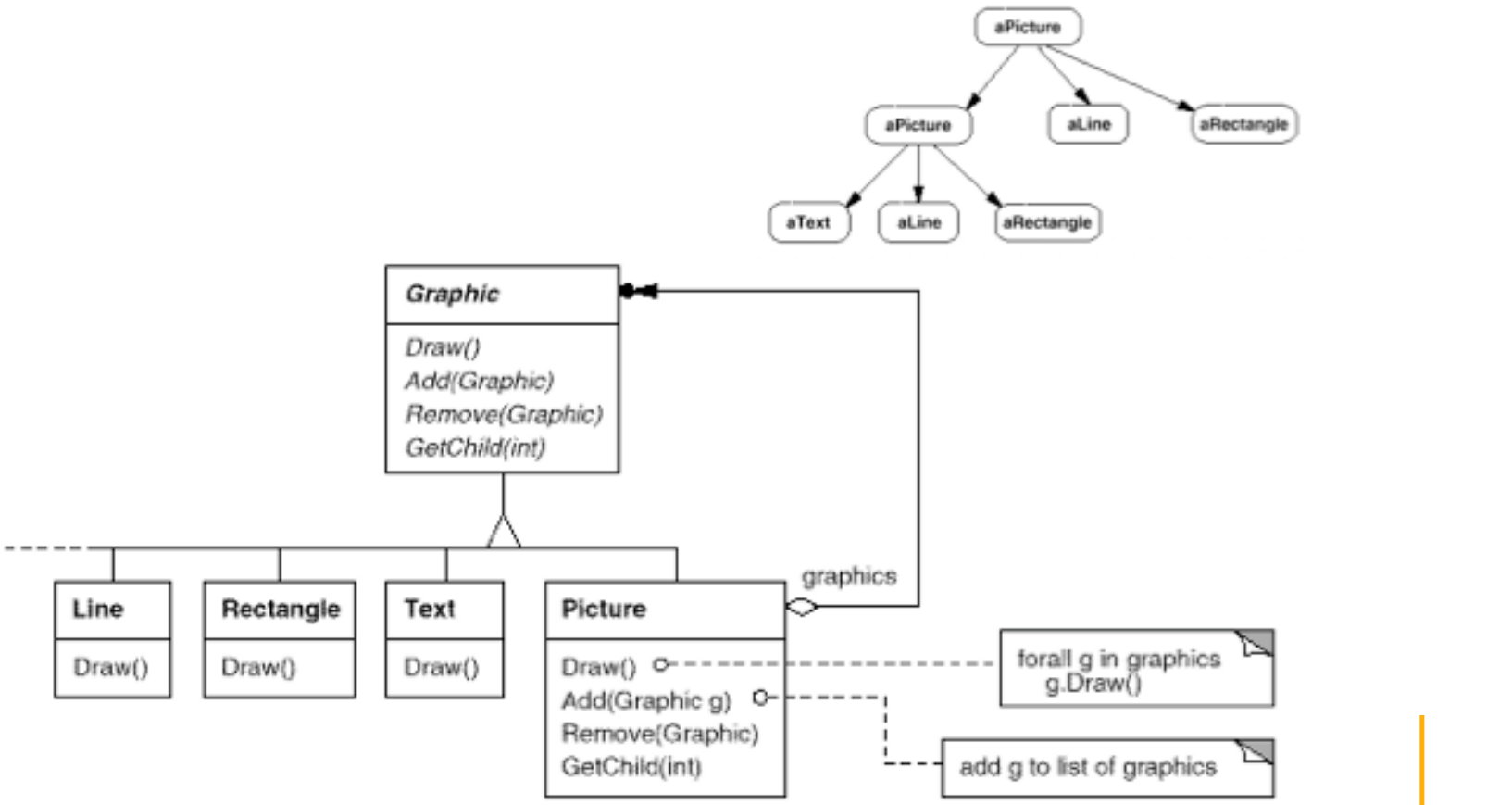


Composite Pattern Applicability

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

Composite Pattern Possible Design



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

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

Composite Pattern Collaborations

Clients use the Component class interface to interact with objects in the composite structure.

Leaves handle requests directly.

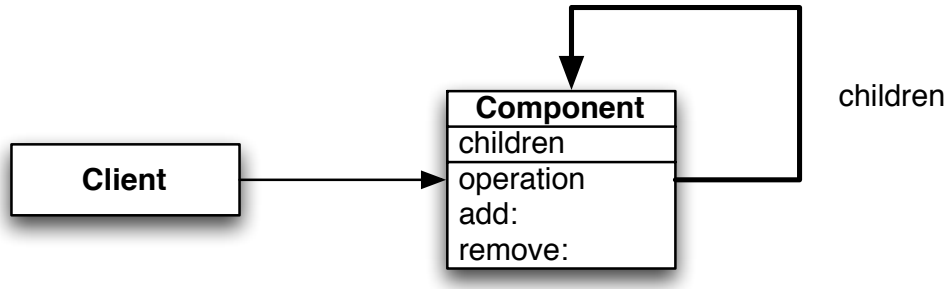
Composites forward requests to its child components

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

An Alternate Structure

Again structure is not intent!



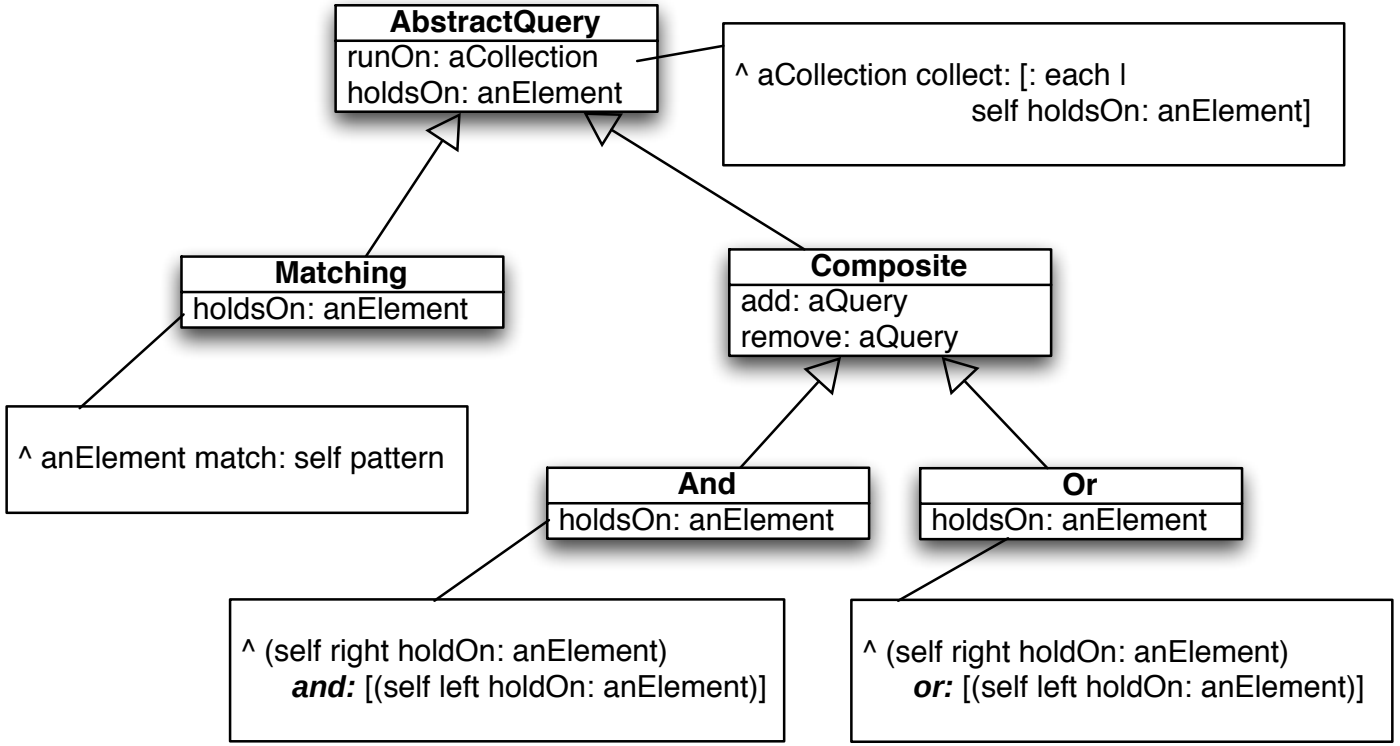
Queries...

- 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)

A Possible Solution



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

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:)

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

Other Patterns

- Composite and Visitors
  - Visitors walks on structured objects

- Composite and Factories
  - Factories can create composite elements

Patterns...

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

Some Creational Patterns

Abstract factory

Builder

Factory Method

Prototype

Singleton

Some Structural Patterns

Adapter
Bridge
Composite
Decorator
Façade
Flyweight
Proxy

Some Behavioral Patterns

Chain of responsibility

Command

Interpreter

Iterator

Mediator

Memento

Observer

State

Strategy

Template Method

Visitor

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!

About Pattern Implementation

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

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

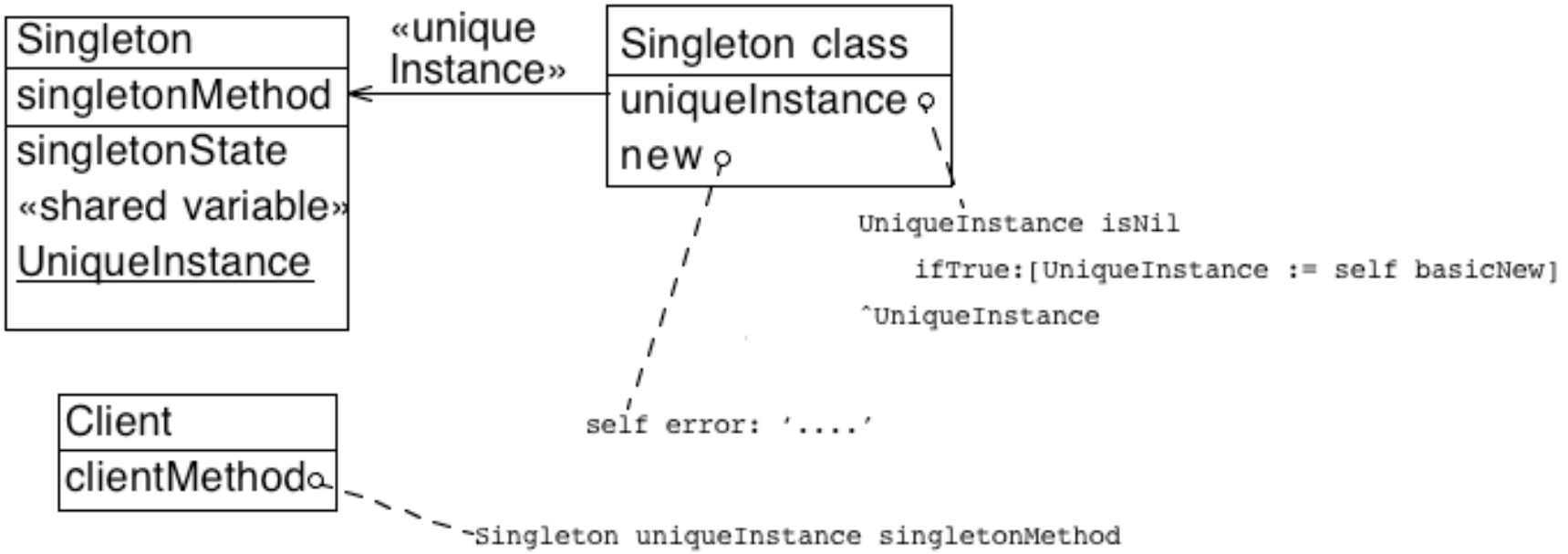
Singleton

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

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.

Singleton Possible Structure



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
        ifTrue: [ uniqueInstance := self basicNew initialize].
  ^uniqueInstance
```


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***?

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,...).

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

Implementation Issues

classVariable or class instance variable

classVariable

- One singleton for a complete hierarchy

Class instance variable

- One singleton per class

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'
```


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
```


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!

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?

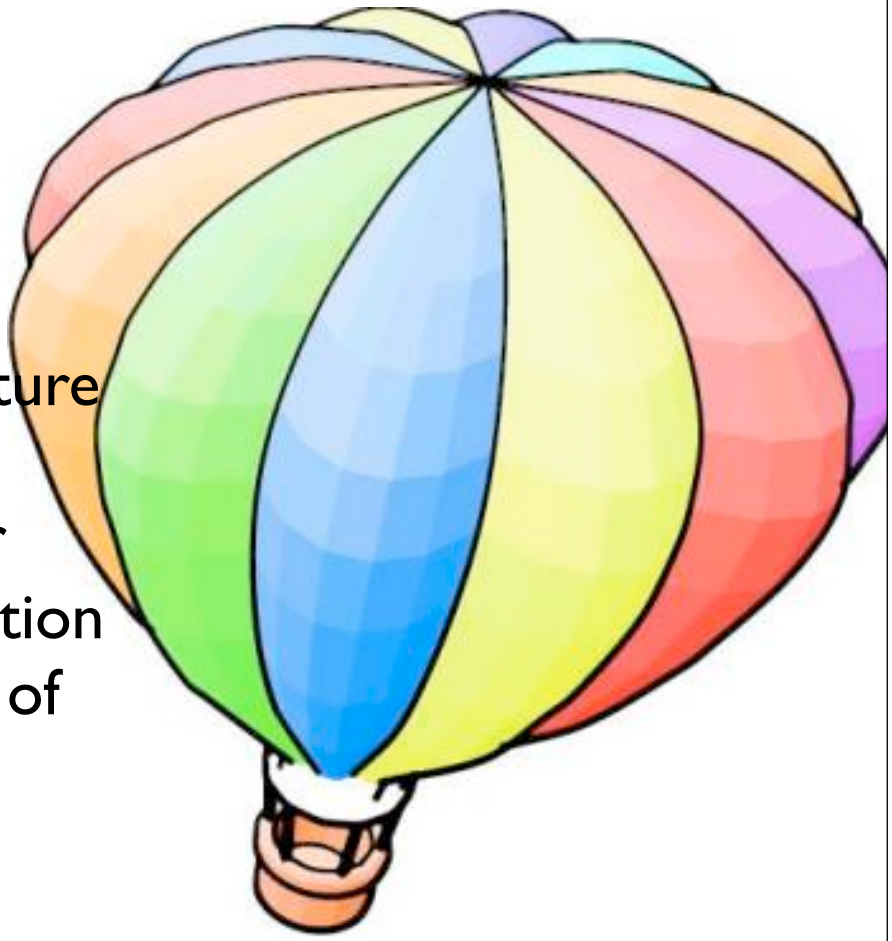
Singleton for access are as bad as global variables

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

Visitor

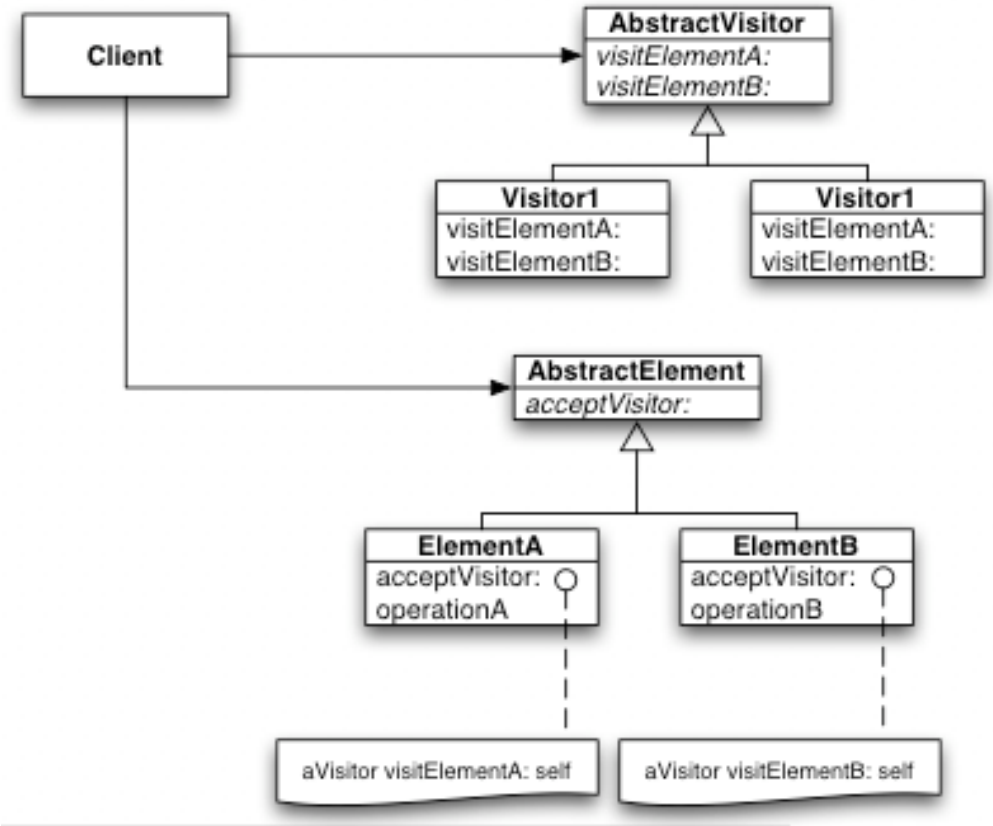
Represent an operation to be performed on the elements of an object structure in a class separate from the elements themselves. Visitor lets you define a new operation *without* changing the classes of the elements on which it operates.



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.

Visitor Possible Structure



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

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

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.

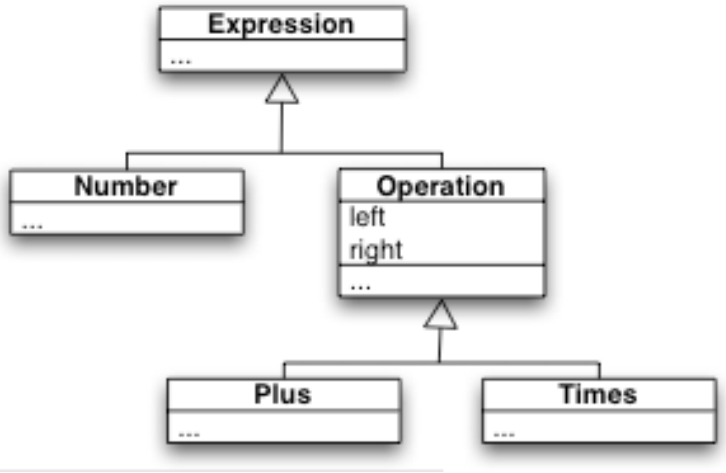
Question: But how do we know what to choose up-front?

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
...
```


Visitor Toy Example: ParseTree



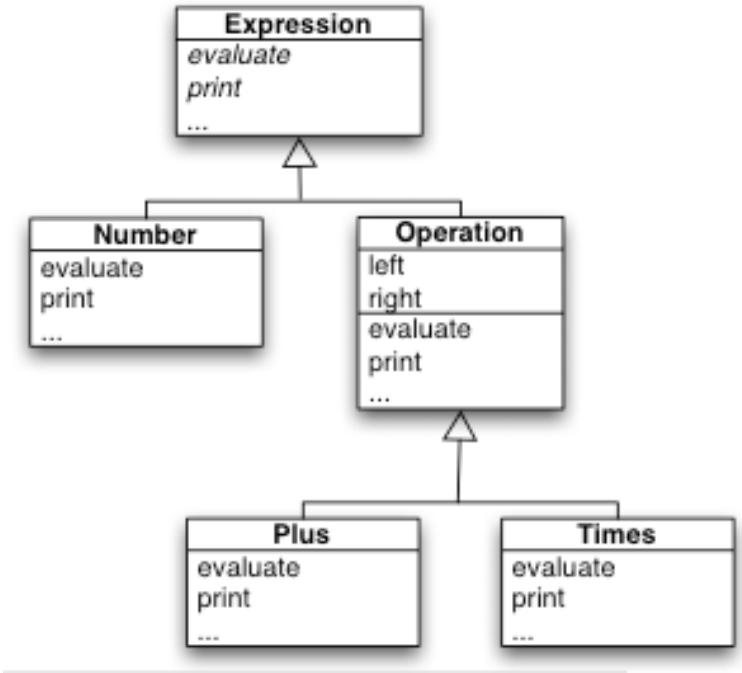
Implementing the Actions

Two solutions:

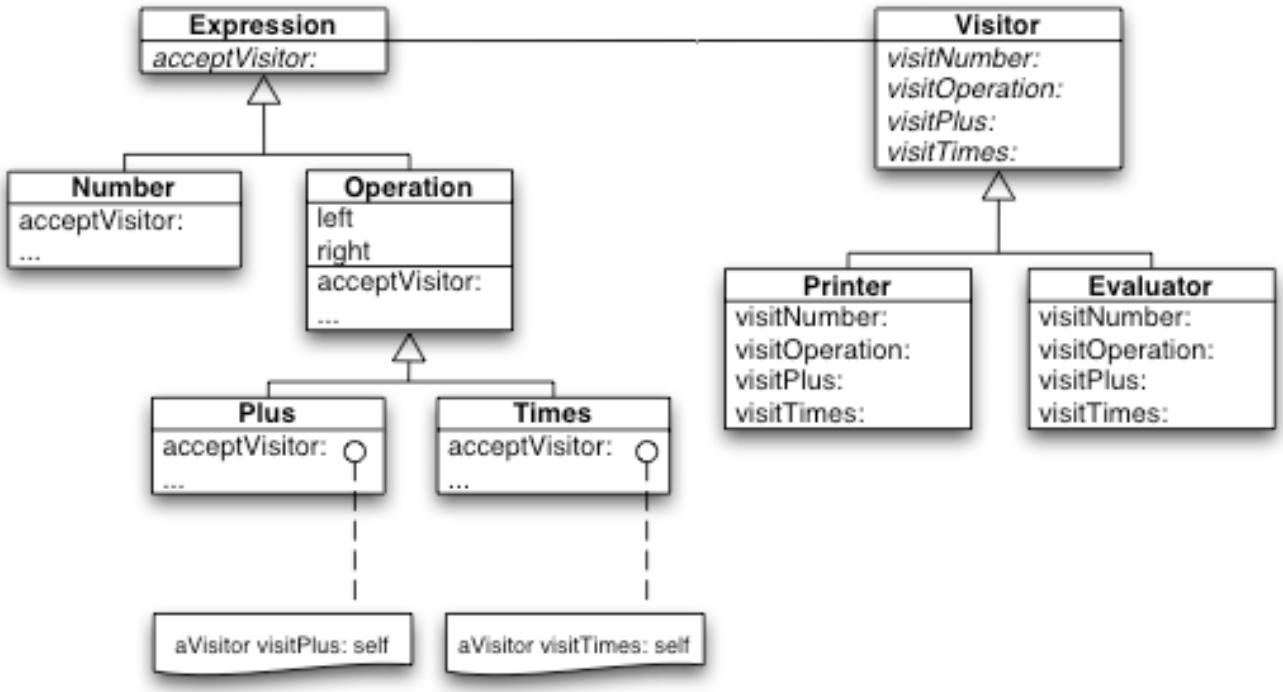
add methods for evaluating, printing, ... on Expression and its subclasses

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

Visitor Toy Example Solution 1



Visitor Toy Example 2



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.

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!

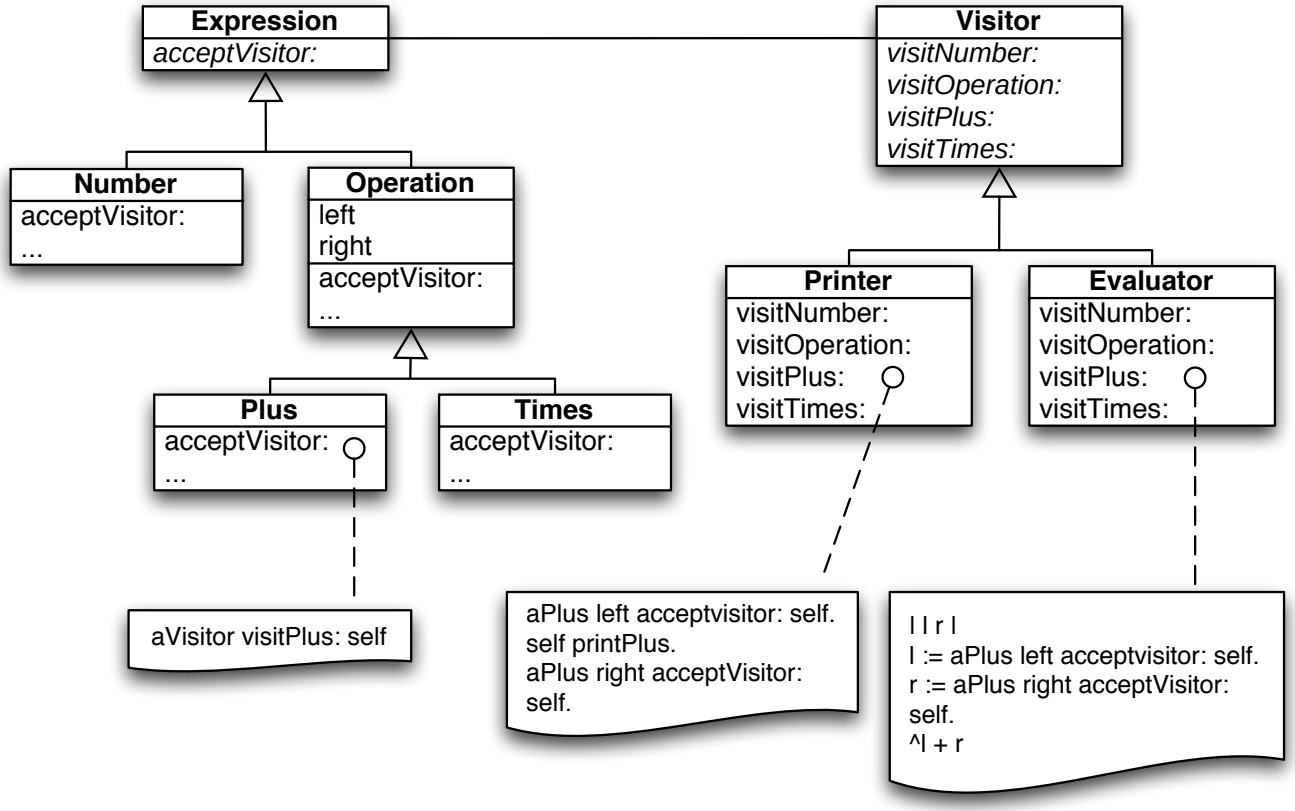
Controlling the traversal

Somewhere in the visitor, items are traversed.

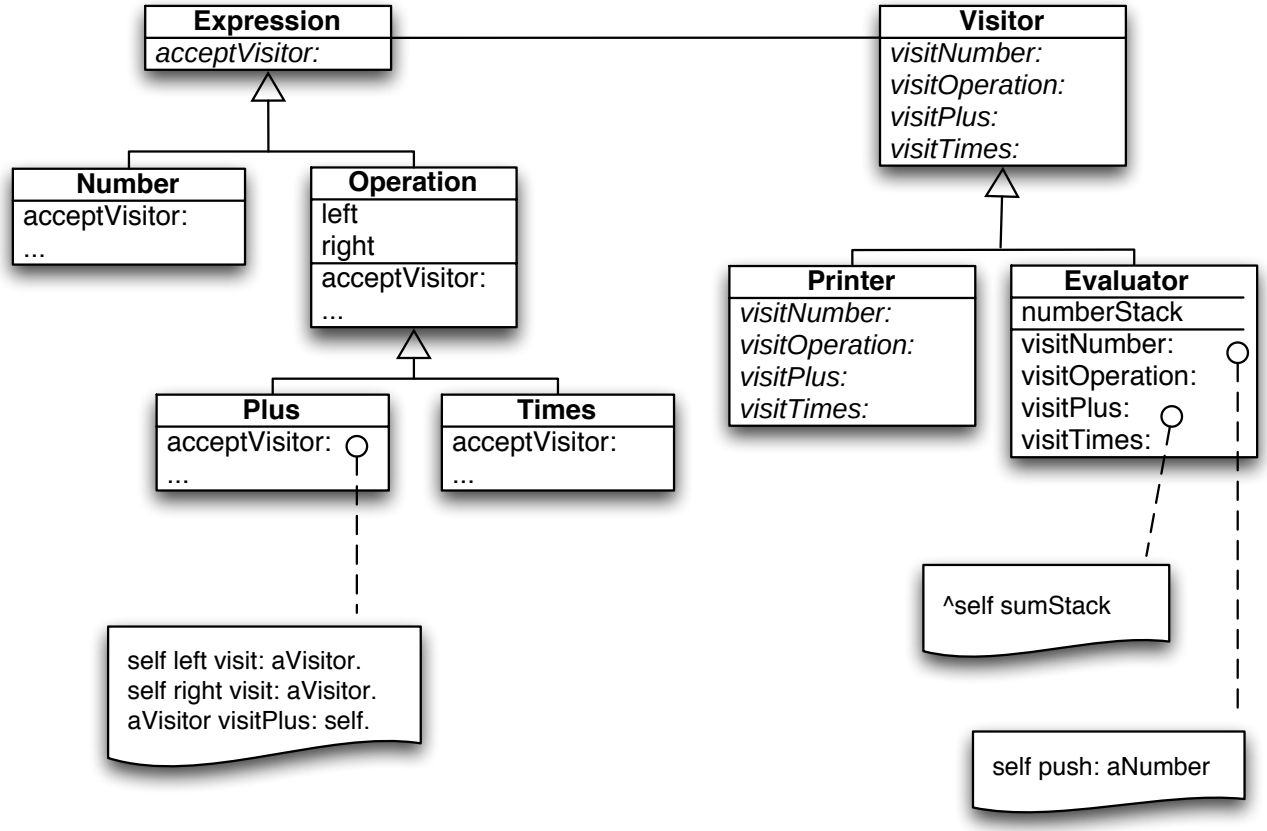
Different places where the traversal can be implemented:

- in the visitor
- on the items hierarchy

Traversal on the Visitor



Traversal on the Items



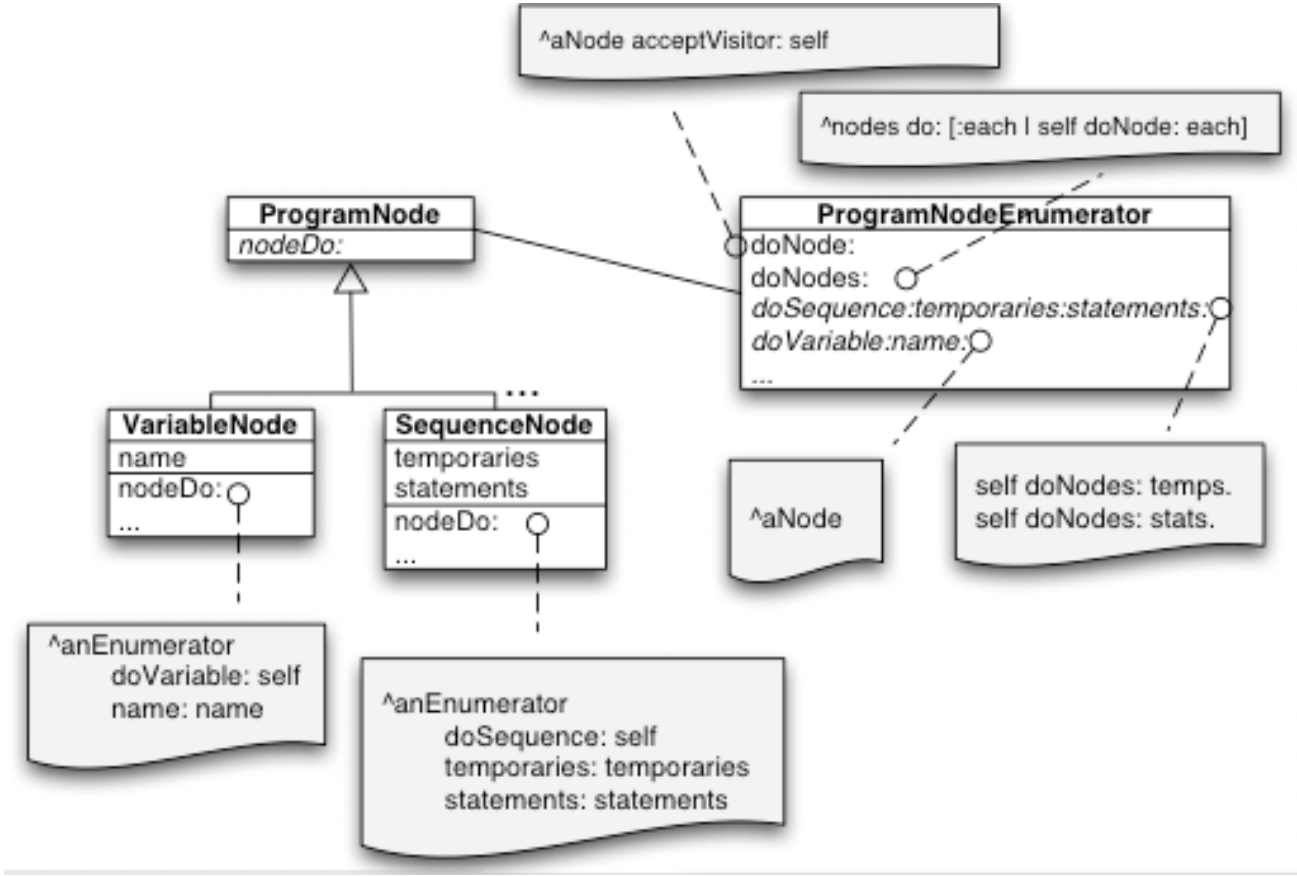
Granularity of Visit Methods

Sometimes you can pass context information with the visit methods

So visitors have more information for implementing their operations

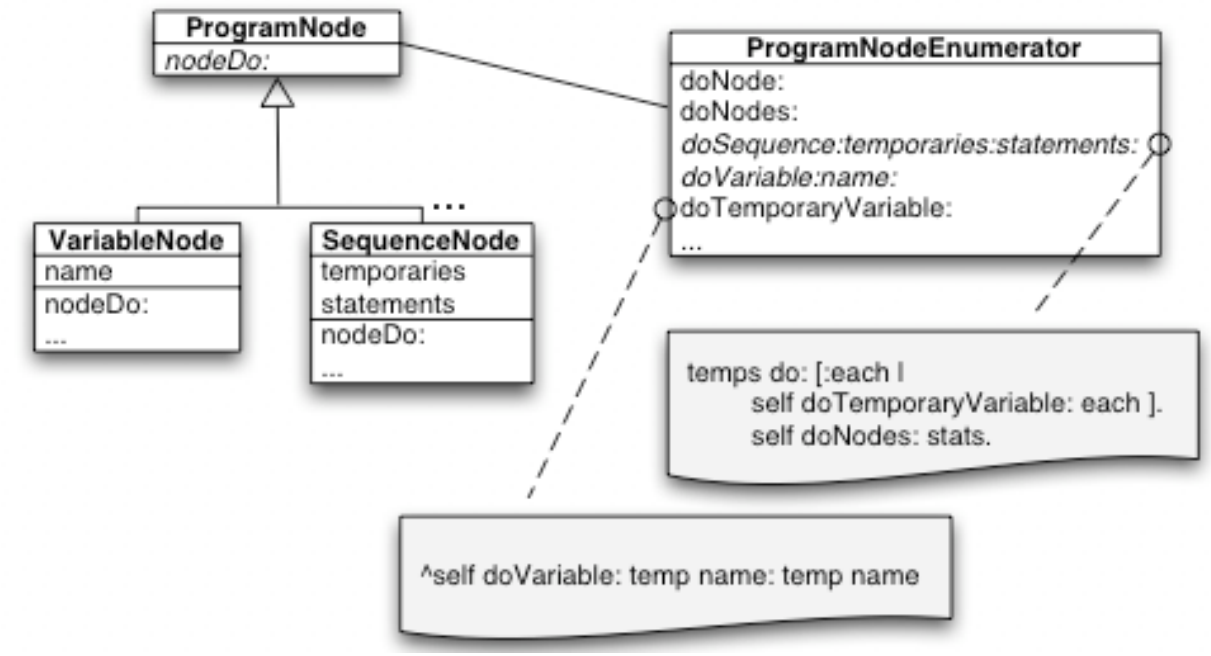
Granularity of Visit Methods

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!

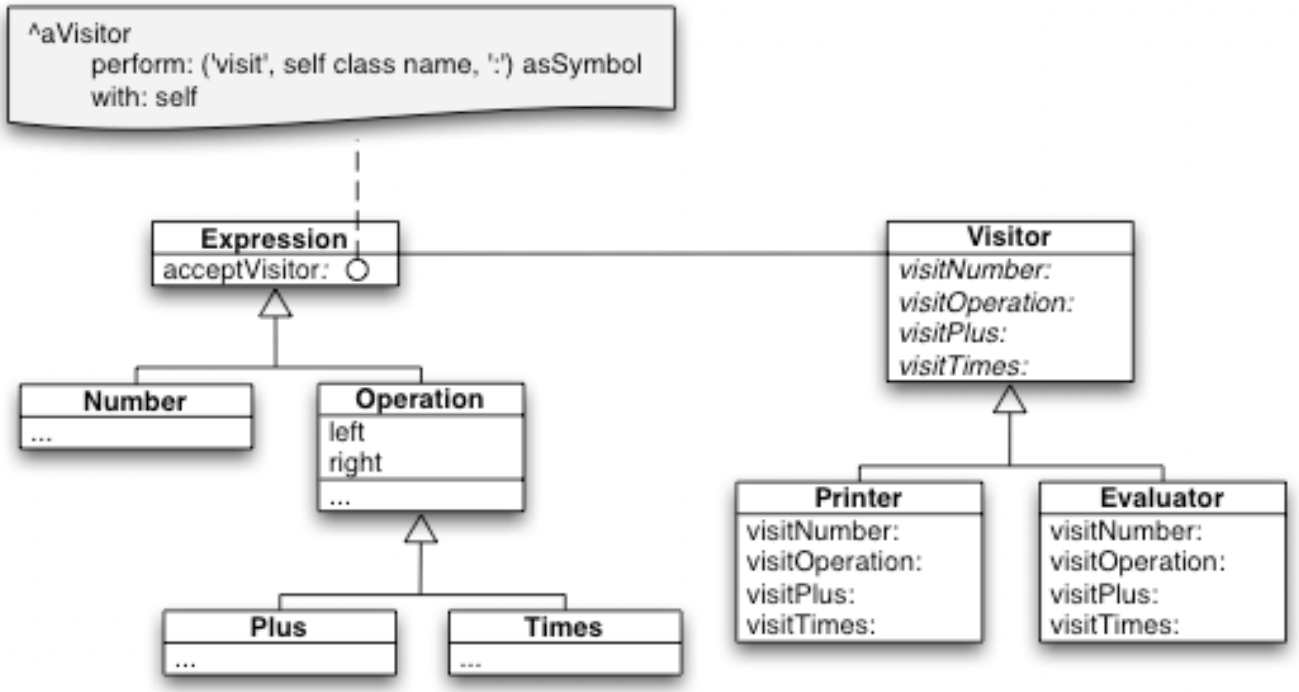
This can be taken as advantage:

- 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
        ifTrue: [ self formatWihtSimpleAlgo]
        ifFalse: [ formatting == #Tex
                    ifTrue: [self formatWithTex]

                ....]
```


Alternative

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

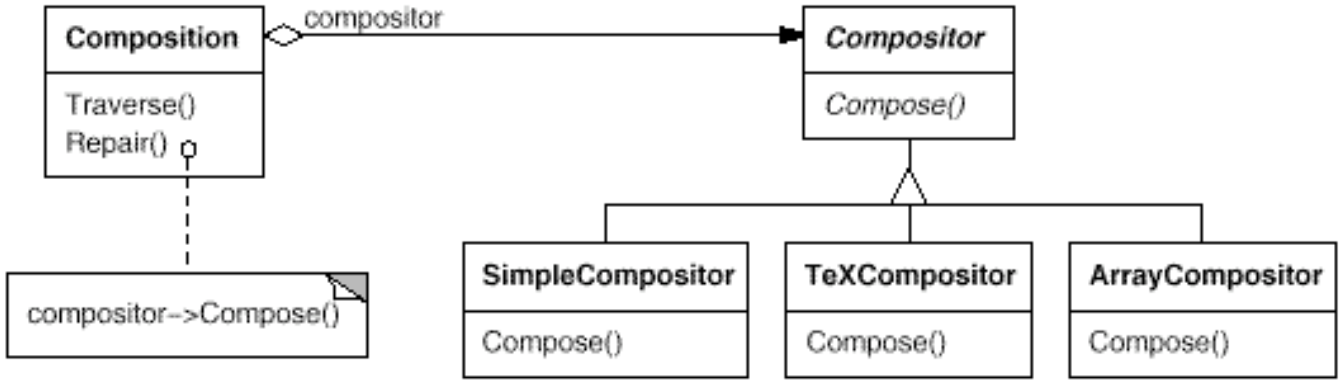
Still your class gets complex...

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



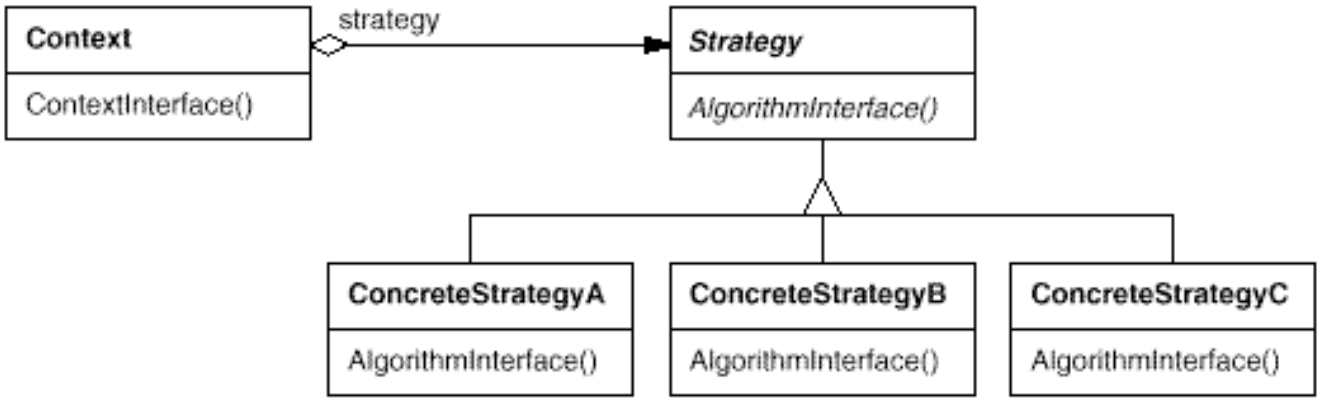
When

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

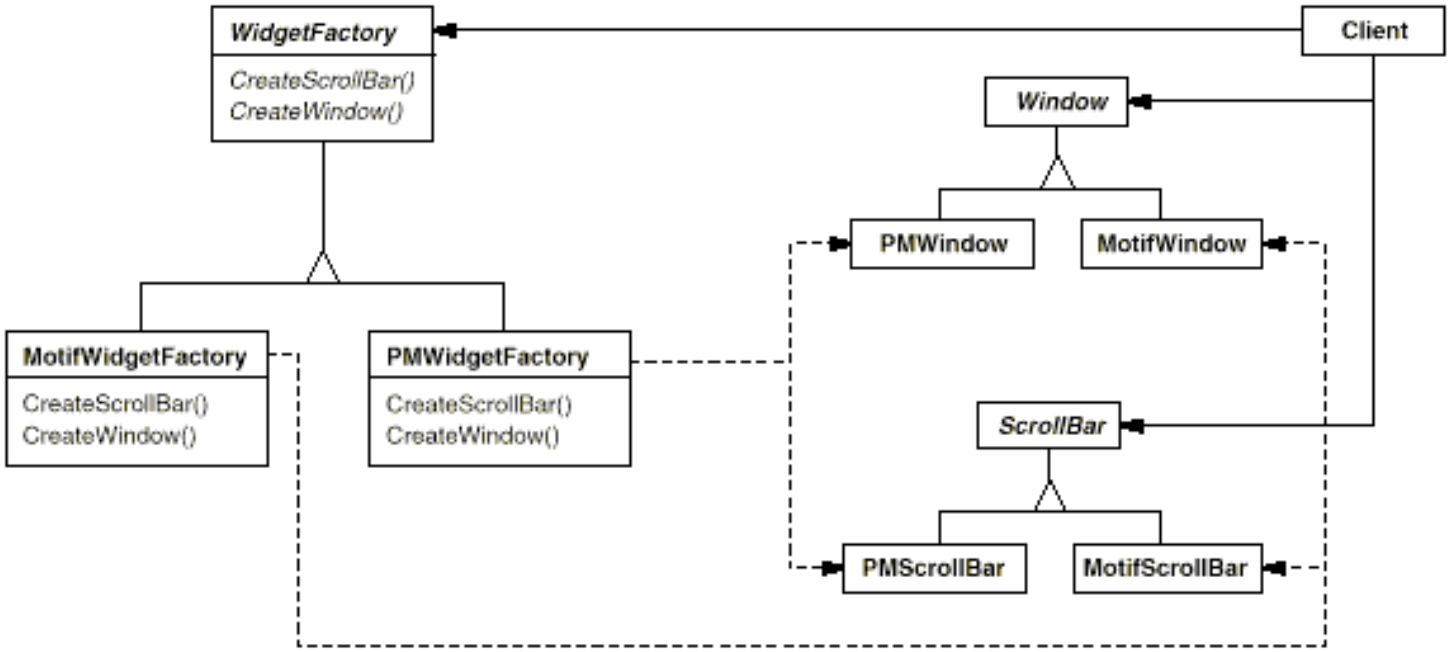
Abstract Factory Motivation

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

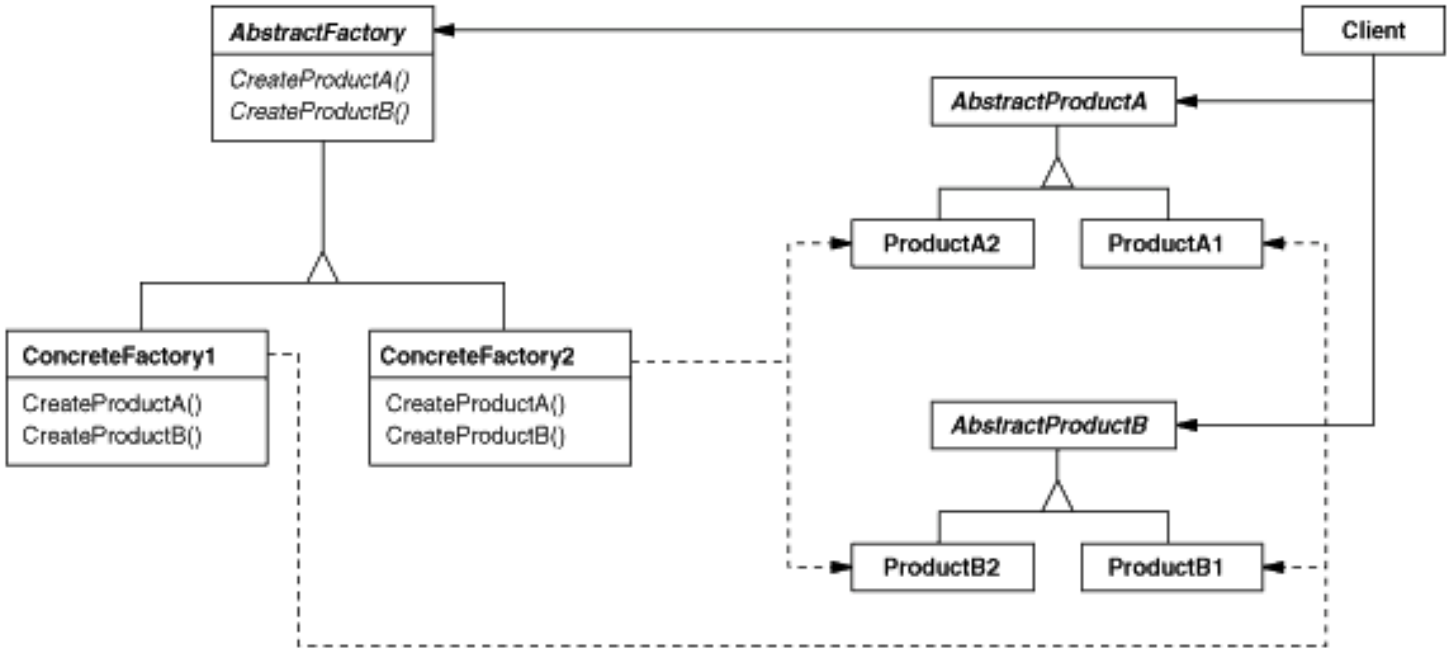
a system should be independent of how its products are created, composed, and represented

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

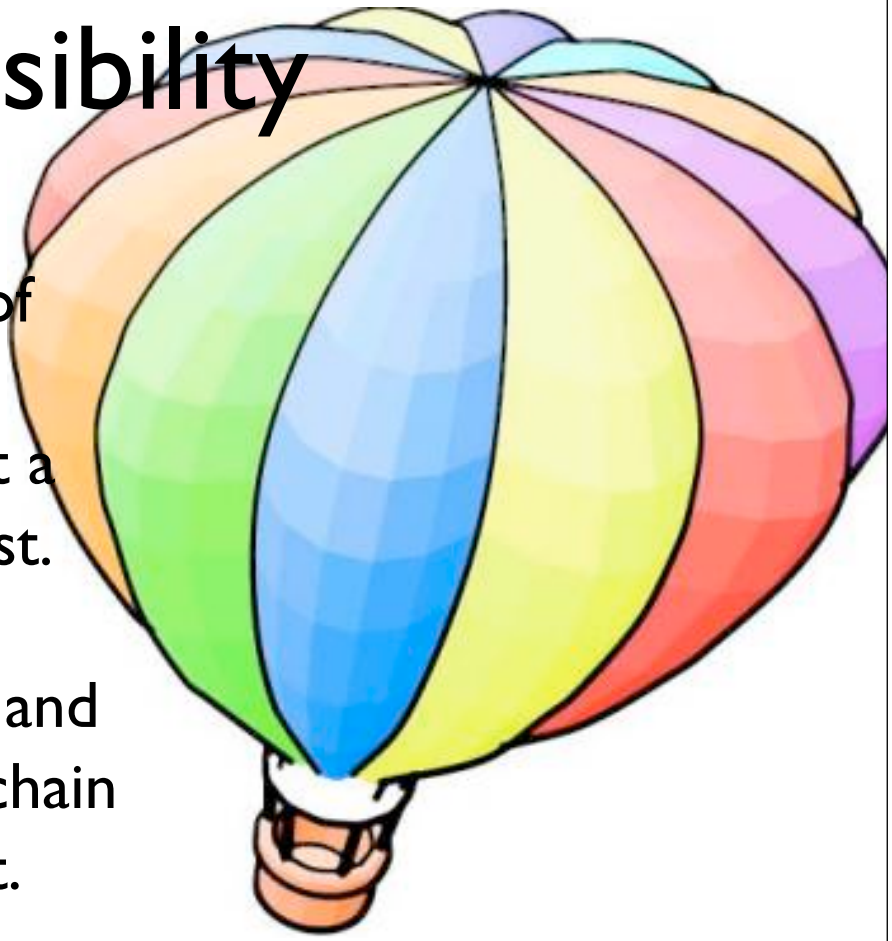
But Builder is in charge of ***assembling*** parts

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.

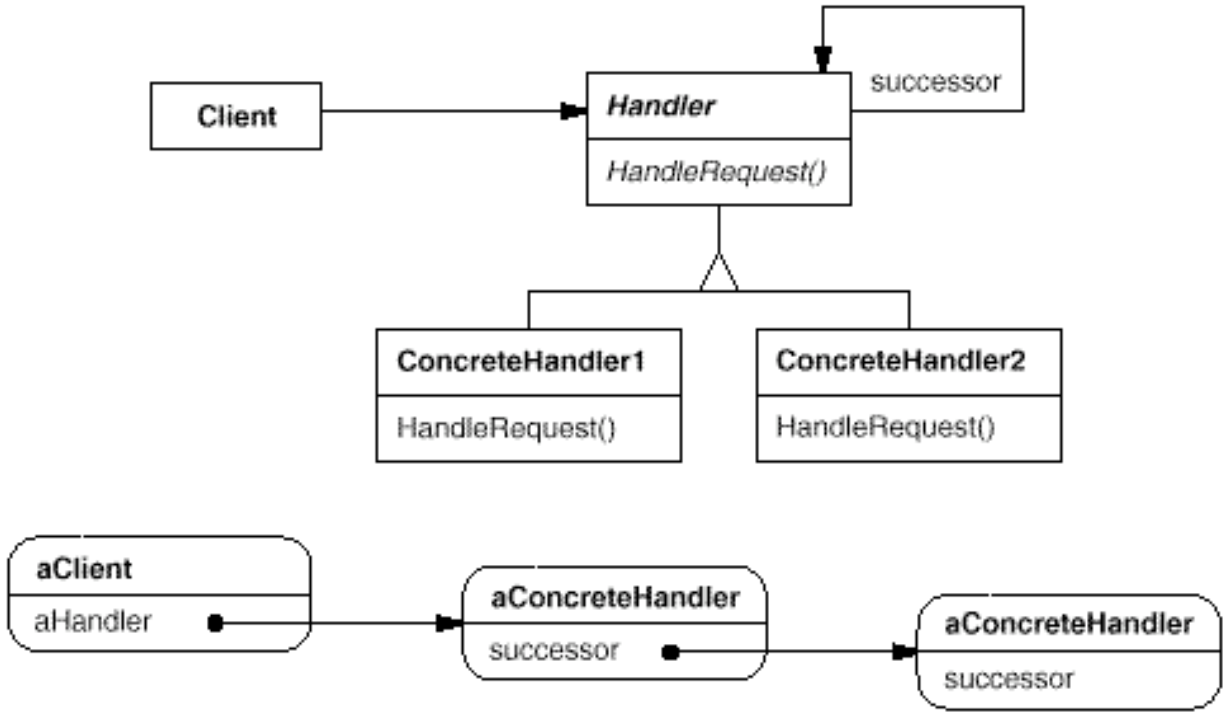
Motivation

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

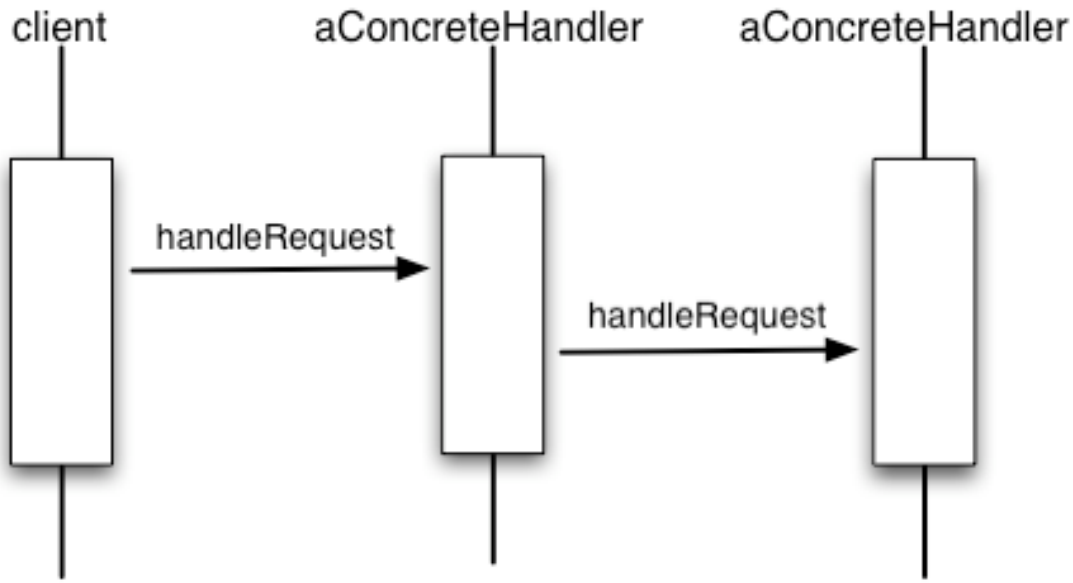
Client

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