Softwaretechnik

Design Patterns

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Design Patterns (1)

- solutions for specific problems in object-oriented software design
- specific description or template to solve problems
  - recurring problems
  - special cases
- relationships and interactions between classes or objects
  - without specifying the final application, classes, objects

- Gamma, Helm, Johnson, Vlissides: Design Patterns, Elements of Reusable Object-Oriented Software, Addison Wesley, 1995.[1]

[1] Gang of Four

Design Patterns (2)

- recurring patterns of collaborating objects
- practical knowledge from practicians (best practices)
- developer's vocabulary for communication
- structuring of code (microarchitectures)
- goals: flexibility, maintainability, communication, reuse
- each pattern emphasizes certain aspects
  flexibility vs. overhead
- alternative approaches and combinations possible
- task: which (combination of) pattern(s) is best
- class-based $\leftrightarrow$ object-based patterns
- inheritance $\leftrightarrow$ delegation

1. Do program against an interface, not again an implementation
   - Many interfaces and abstract classes beside concrete classes
   - Generic frameworks instead of direct solutions
2. Do prefer object composition instead of class inheritance
   - Delegate tasks to helper objects
3. Decoupling
   - Objects less interdependent
   - Indirection as an instrument
   - Additional helper objects

Inheritance = White-box reuse

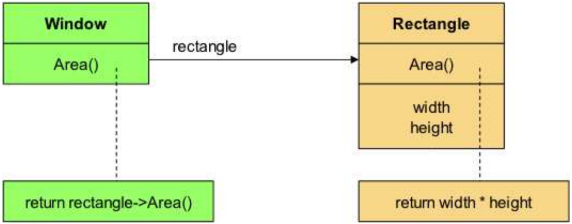
- Reuse by inheritance
- Inheritance is static
- Internals of base classes are visible
- Inheritance breaks encapsulation

Composition = Black-box reuse

- Reuse by object composition
- Needs well-formed interfaces for all objects
- Internals of base classes are hidden

Delegation

- Object composition is mighty as inheritance
- Usage of delegation (indirection)



- But
  - More objects involved
  - Explicit object references
  - No this-pointers
- Dynamic approach, hard to comprehend, maybe inefficient at runtime

Indirection

- A recurring pattern found in all design patterns
  - List x = new ArrayList(); // direct example
  - List x = aListFactory.createList(); // indirect example
- Indirection
  - Object creation
  - Method calls
  - Implementation
  - Complex algorithms
  - Excessive coupling
  - Extension of features
- Do spend additional objects!

- Coupling
  - List x = new ArrayList();
  - Implementation class is hard-wired
  - Usage of implementation class instead interface
  - Replacement of implementation class is hard
- Decoupling
  - List x = aListFactory.createList();
  - Creates an object indirectly
- Patterns: Abstract Factory, Factory Method, Prototype

- Coupling
  - Hard wiring of method calls
  - No changes without compiling
- Decoupling
  - Objectification of methods
  - Replaceable at runtime
- Patterns: Chain of Responsibility, Command

- Dependencies on hardware and software platforms
  - External OS-API's may vary
  - Platform-independent systems as possible
  - Patterns: Abstract Factory, Bridge
- Dependencies on object representation or implementaion
  - Clients know, how and where an object is represented, stored, implemented, etc.
  - Clients must be changed, even if the interfaces don't change
  - Patterns: Abstract factory, Bridge, Memento, Proxy

- Fixedness though hard-wiring
  - Catching all cases of an algorithm
    - Many conditional choices (if, then, else)
    - Conditional choices by classes instead of if, then, else
  - Changes, extensions, optimizations bring further conditional choices
  - Decouple parts of algorithm that might change in the future
- Flexibilization by decoupling additional algorithm objects
- Patterns: Builder, Iterator, Strategy, Template Method, Visitor

- Too close coupled objects
  - Leads to monolithic systems
  - Single objects can't be used isolated
- Decoupling
  - Additional helper objects
- Patterns: Abstract Factory, Bridge, Chain of Responsibility, Command, Facade, Mediator, Observer

- Coupling in class hierarchies
  - Through inheritance
  - Implementing a sub class needs knowledge of base class
  - Isolated overriding of a method not possible
  - Too many sub classes
  - Decoupling by additional objects
  - Patterns: Bridge, Chain of Responsibility, Composite, Decorator, Observer, Strategy
- When a class can't be changed...
  - No source code available
  - Changes have to many effects
  - Patterns: Adapter, Decorator, Visitor

Classification of Design Patterns

Purpose

Creational Patterns deal with object creation
: Singleton, Abstract Factory, Builder, (and Factory Method, Prototype)

Structural Patterns composition of classes or objects
: Facade, Proxy, Decorator (and Adapter, Bridge, Flyweight, Composite)

Behavioral Patterns interaction of classes or objects
: Observer, Visitor, (and Command, Iterator, Memento, State, Strategy)

Class static relationships between classes (inheritance)

Object dynamic relationships between objects

Standard Template

- Intent
- Motivation
- Applicability
- Structure
- Participants
- Collaborations
- Consequences
- Implementation
- Sample Code
- Known Uses
- Related Patterns

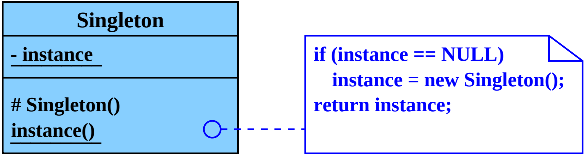
Creational Pattern: Singleton

Intent

- class with exactly one object (global variable)
- no further objects are generated
- class provides access methods

Motivation

- to create factories and builders



Applicability

- exactly one object of a class required
- instance globally accessible

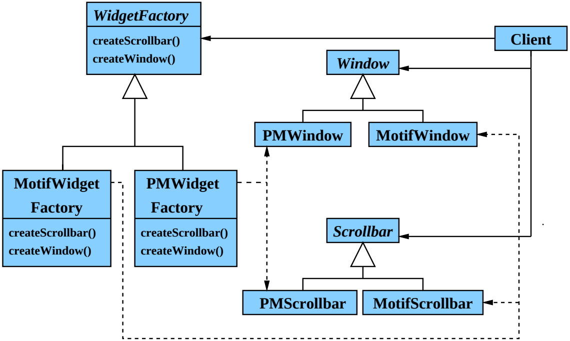
Consequences

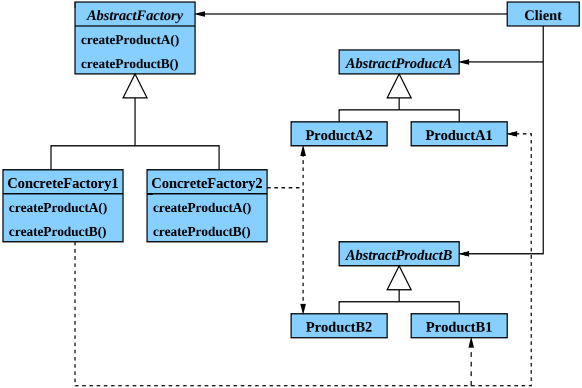
- access control on singleton
- structured address space (compared to global variables)

Intent

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

- user interface toolkit supporting multiple look-and-feel standards
  e.g., Motif, Presentation Manager




AbstractFactory
createProductA()
createProductB()
Client
AbstractProductA
ProductA2
ProductA1
ConcreteFactory1
createProductA()
createProductB()
ConcreteFactory2
createProductA()
createProductB()
AbstractProductB
ProductB2
ProductB1

- independent of how products are created, composed, and represented
- configuration with one of multiple families of products
- related products must be used together
- reveal only interface, not implementation

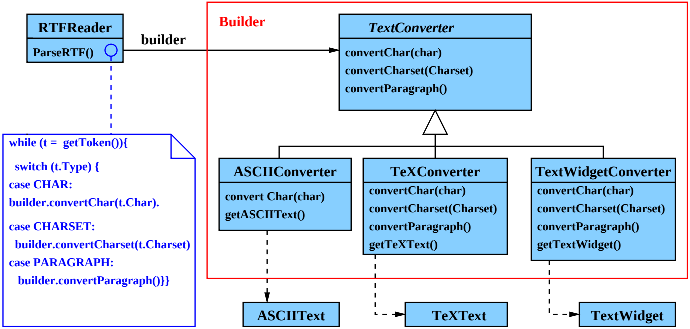
Consequences

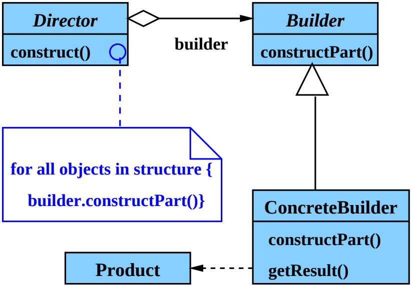
- product class names do not appear in code
- exchange of product families easy
- requires consistency among products

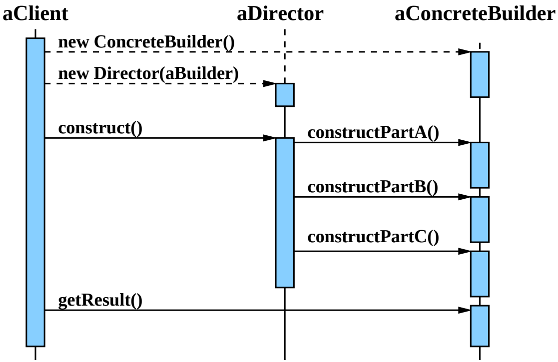
Intent

- Separate the construction of a complex object from its representation so that the same construction process can create different representations.

- read RTF and translate in different exchangeable formats




Director
construct()
builder
Builder
constructPart()
for all objects in structure {
builder.constructPart()}
ConcreteBuilder
constructPart()
getResult()
Product



aClient
aDirector
aConcreteBuilder
new ConcreteBuilder()
new Director(aBuilder)
construct()
constructPartA()
constructPartB()
constructPartC()
getResult()

- reusable for other directors (*e.g.* XMLReader)

Difference to Abstract Factory

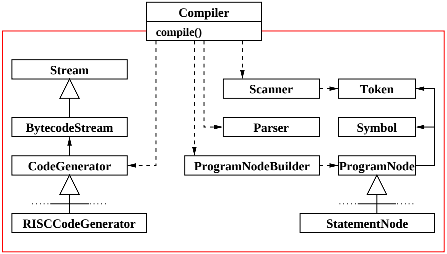
- Builder assembles a product step-by-step (parameterized over assembly steps)
- Abstract Factory returns complete product

Intent

- provide a unified interface to a set of interfaces in a subsystem

Motivation

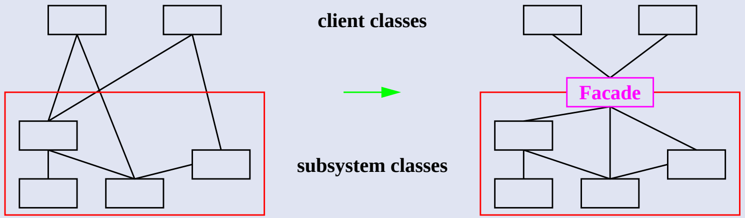
- compiler subsystem contains Scanner, Parser, Code generator, etc
- Facade combines interfaces and offers new `compile()` operation



Compiler
compile()
Stream
Scanner
Token
BytecodeStream
Parser
Symbol
CodeGenerator
ProgramNodeBuilder
ProgramNode
RISCCodeGenerator
StatementNode

- simple interface to complex subsystem
- many dependencies between clients and subsystem → Facade reduces coupling
- layering

Structure



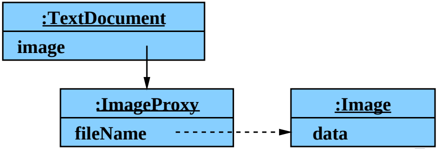
- shields clients from subsystem components
- weak coupling: improves flexibility and maintainability
- often combines operations of subsystem to new operation
- with public subsystem classes: access to each interface

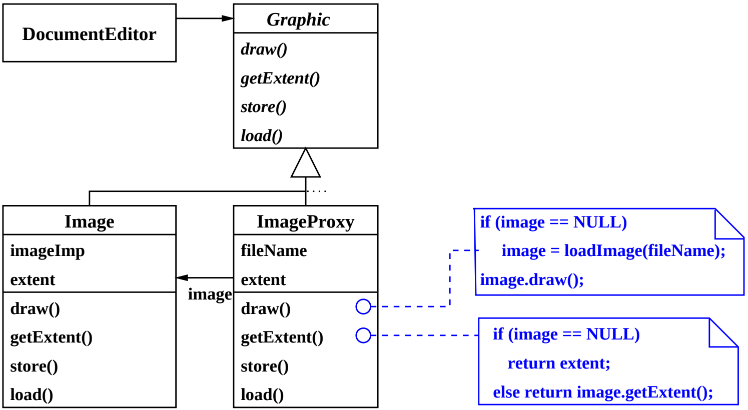
Intent

- control access to object

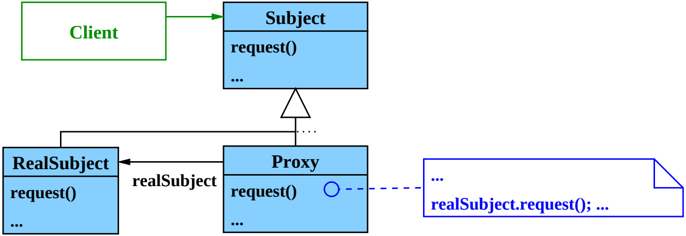
Motivation

- multi-media editor loads images, audio clips, videos etc on demand
- represented by proxy in document
- proxy loads the “real object” on demand





DocumentEditor
Graphic
draw()
getExtent()
store()
load()
Image
imageImp
extent
draw()
getExtent()
store()
load()
image
ImageProxy
fileName
extent
draw()
getExtent()
store()
load()
if (image == NULL)
image = loadImage(fileName);
image.draw();
if (image == NULL)
return extent;
else return image.getExtent();



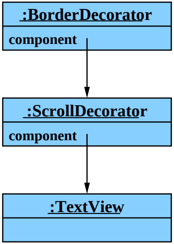
Client
Subject
request()
...
RealSubject
request()
...
realSubject
Proxy
request()
...
...
realSubject.request(); ...

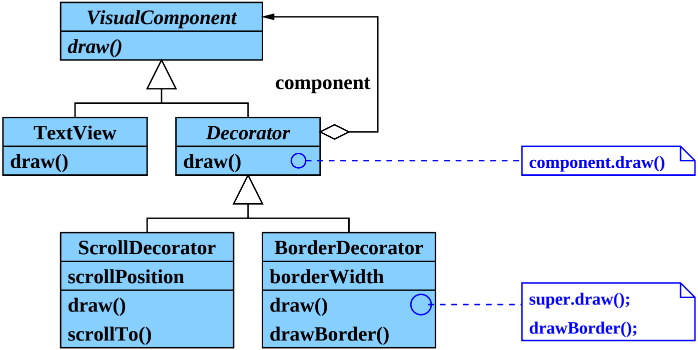
1. *remote proxy* communication with object on server (CORBA)
2. *virtual proxy*
   - creates expensive objects on demand
   - delays cost of creation and initialization
3. *protection proxy* controls access permission to original object
4. *smart reference* additional operations: reference counting, locking, copy-on-write

Intent

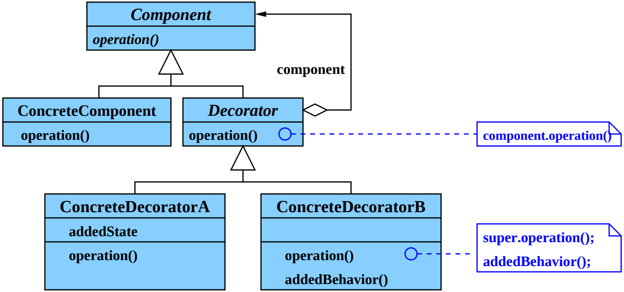
- extend object's functionality dynamically
- more flexible than inheritance

- graphical object can be equipped with border and/or scroll bar
- decorator object has same interface as the decorated object
- decorated forwards requests
- recursive decoration





VisualComponent
draw()
component
TextView
draw()
Decorator
draw()
component.draw()
ScrollDecorator
scrollPosition
draw()
scrollTo()
BorderDecorator
borderWidth
draw()
drawBorder()
super.draw();
drawBorder();



Applicability

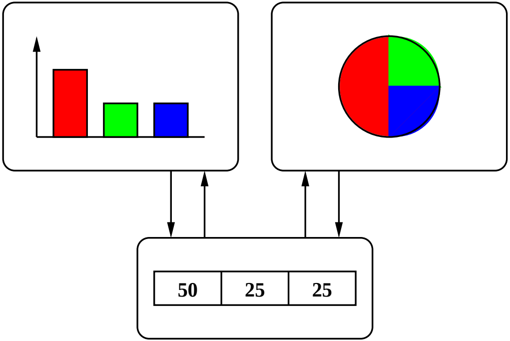
- dynamically add responsibilities to individual objects
- for withdrawable responsibilities
- when extension by inheritance is impractical

- more flexible than inheritance
- avoids feature-laden classes high up in the hierarchy
- decorator $\neq$ component
- lots of little objects $\rightarrow$ hard to learn and debug

Intent

- define $1 : n$-dependency between objects
- state-change of one object notifies all dependent objects

- maintain consistency between internal model and external views



Behavioral Pattern: Observer

Structure (1)

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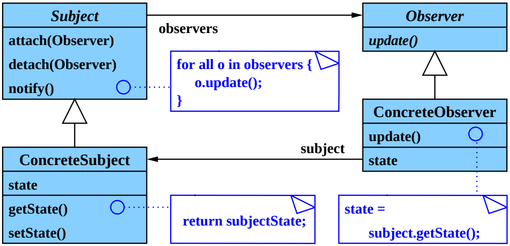
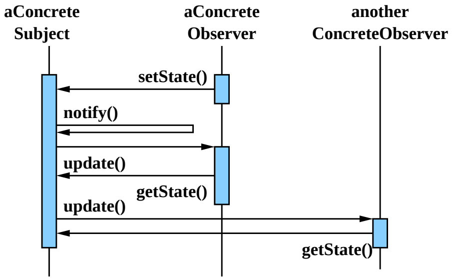



aConcrete Subject
aConcrete Observer
another ConcreteObserver
setState()
notify()
update()
getState()
update()
getState()

- objects with at least two mutually dependent aspects
- propagation of changes
- anonymous notification

Consequences

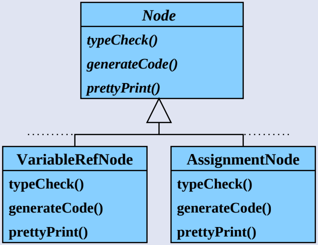
- `Subject` and `Observer` are independent (abstract coupling)
- broadcast communication
- observers dynamically configurable
- simple changes in `Subject` may become costly
- granularity of `update()`

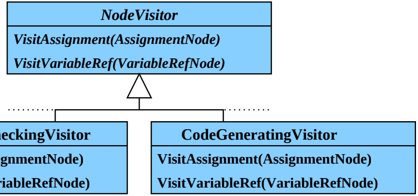
Intent

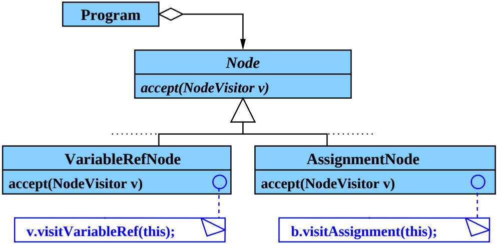
- represents operations on an object structure by objects
- new operations without changing the classes

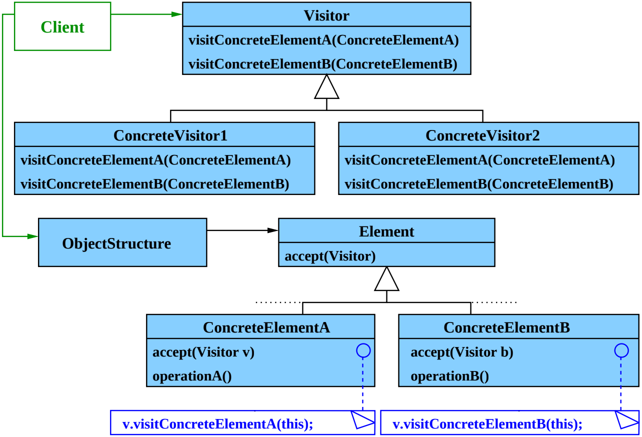
- processing of a syntax tree in a compiler: type checking, code generation, pretty printing, ...
- naive approach: put operations into node classes → hampers understanding and maintainability
- here: realize each processing step by a visitor

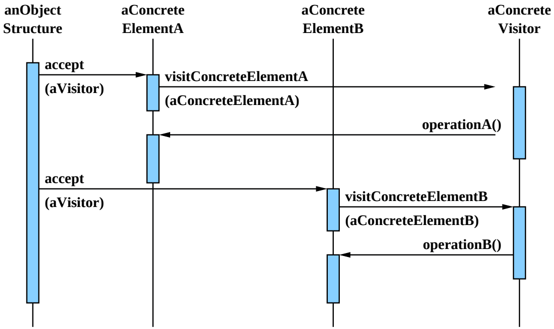
without visitor




NodeVisitor
VisitAssignment(AssignmentNode)
VisitVariableRef(VariableRefNode)
TypeCheckingVisitor
VisitAssignment(AssignmentNode)
VisitVariableRef(VariableRefNode)
CodeGeneratingVisitor
VisitAssignment(AssignmentNode)
VisitVariableRef(VariableRefNode)


Program
Node
accept(NodeVisitor v)
VariableRefNode
accept(NodeVisitor v)
AssignmentNode
accept(NodeVisitor v)
v.visitVariableRef(this);
b.visitAssignment(this);


Client
Visitor
visitConcreteElementA(ConcreteElementA)
visitConcreteElementB(ConcreteElementB)
ConcreteVisitor1
visitConcreteElementA(ConcreteElementA)
visitConcreteElementB(ConcreteElementB)
ConcreteVisitor2
visitConcreteElementA(ConcreteElementA)
visitConcreteElementB(ConcreteElementB)
ObjectStructure
Element
accept(Visitor)
ConcreteElementA
accept(Visitor v)
operationA()
ConcreteElementB
accept(Visitor b)
operationB()
v.visitConcreteElementA(this);
v.visitConcreteElementB(this);



anObject Structure
aConcrete ElementA
aConcrete ElementB
aConcrete Visitor
accept
(aVisitor)
visitConcreteElementA
(aConcreteElementA)
operationA()
accept
(aVisitor)
visitConcreteElementB
(aConcreteElementB)
operationB()

- object structure with many differing interfaces; processing depends on concrete class
- distinct and unrelated operations on object structure
- not suitable for evolving object structures

Consequences

- adding new operations easy
- visitor gathers related operations
- adding new `ConcreteElement` classes is hard
- visitors with state
- partial breach of encapsulation