Design Patterns

Softwaretechnik

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- Gamma, Helm, Johnson, Vlissides: Design Patterns, Elements of Reusable Object-Oriented Software, Addison Wesley, 1995.[1]
- Solutions for specific problems in object-oriented software design
  - Catalog
  - Architectural style for software development
- Specific description or template to solve problems
  - Recurring problems
  - Special cases
- Relationships and interactions betweien classes or objects
  - Without specifying the final application, classes, objects

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[1] Gang of Four

Fundamentals of Design Patterns

- Intent
    - Recurring patterns of collaborating objects
    - Practical knowledge from practicians (best practices)
    - Developer's vocabulary for communication
    - Structuring of code (architectures)
- Goals
    - Flexibility
    - Maintainability
    - Communication
    - Reuse

- Aspects
    - Flexibility–Overhead
    - Class-based–Object-based patterns
    - Inheritance–Delegation
- Alternative approaches and combinations possible
    - Which (combination of) pattern(s) is best

Principles of Design Patterns

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

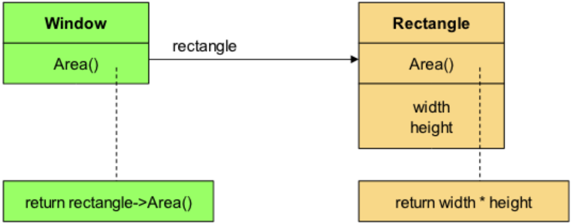
Inheritance = White-box reuse

- 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

- 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

- 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!

Principles of Design Patterns

Indirection (cont)

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- Object creation
  - Coupling
    - List x = new ArrayList();
  - Decoupling
    - List x = aListFactory.createList();
- Method calls
  - Coupling
    - Hard wiring of method calls
    - No changes without compiling
  - Decoupling
    - Objectification of methods
    - Replaceable at runtime
- Implementation
  - Dependencies on hardware and software platforms
    - Platform-independent systems
- Complex algorithms
  - Fixedness though hard-wiring
    - Conditional choices by classes instead of if, then, else
  - Decouple parts of algorithm that might change in the future

Principles of Design Patterns

Indirection (cont)

- Excessive coupling
  - Single objects can't be used isolated
- Decoupling
  - Additional helper objects
- Extension of features (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
- When a class can't be changed...
  - No source code available
  - Changes have to many effects

Classification of Design Patterns

Purpose

Creational Patterns	deal with object creation e.g. Singleton, Abstract Factory, Builder
Structural Patterns	composition of classes or objects e.g. Facade, Proxy, Decorator, Composite, Flyweight
Behavioral Patterns	interaction of classes or objects e.g. Observer, Visitor, Command, Iterator

Scope

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

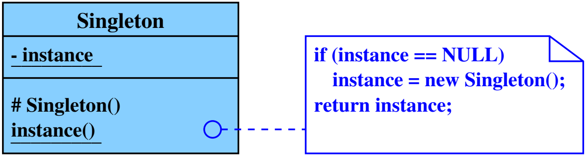
Creational Pattern: Singleton

Intent

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

Motivation

- To create factories and builders



Singleton

- instance

# Singleton()
instance()

```
if (instance == NULL)
   instance = new Singleton();
return instance;
```

Creational Pattern: Singleton

Structure

Applicability

- Exactly one object of a class required
- Instance globally accessible

Consequences

- Access control on singleton
- Structured address space (compared to global variables)

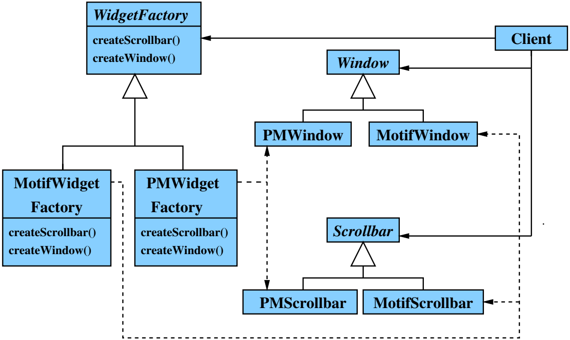
Creational Pattern: Abstract Factory

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

Creational Pattern: Abstract Factory

Motivation



Creational Pattern: Abstract Factory

Structure

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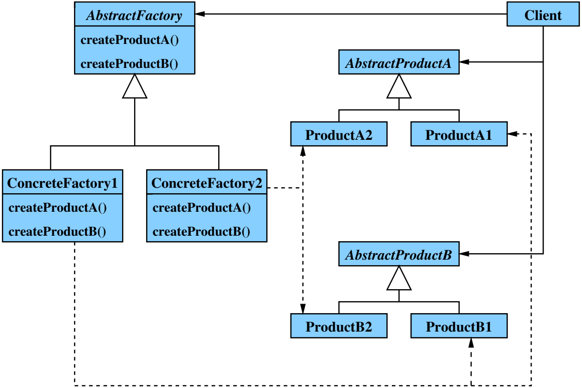

Creational Pattern: Abstract Factory

Applicability

- 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

Creational Pattern: Builder

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

Creational Pattern: Builder

Motivation

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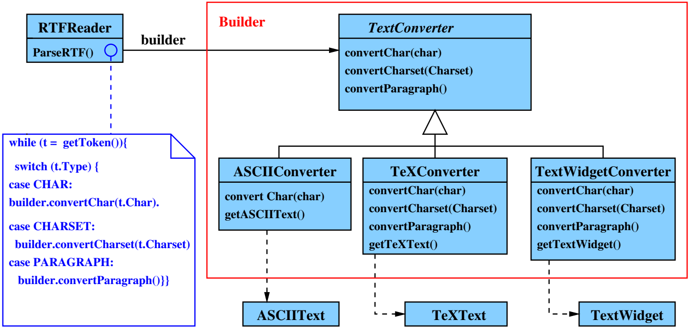
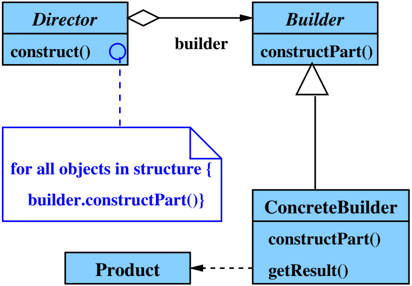


Creational Pattern: Builder

Structure



Creational Pattern: Builder

Consequences

- 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

Structural Pattern: Facade

Intent

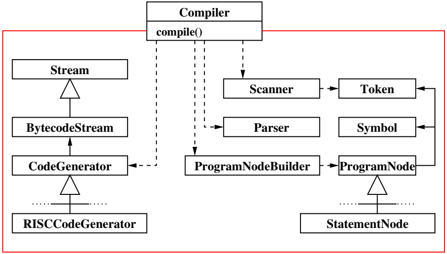
- Provide a unified interface to a set of interfaces in a subsystem

Motivation

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

Structural Pattern: Facade

Motivation (2)

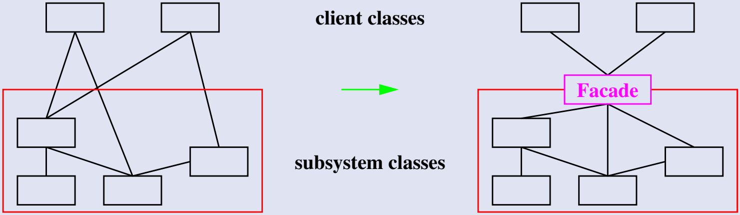


Structural Pattern: Facade

Applicability

- Simple interface to complex subsystem
- Many dependencies between clients and subsystem–Facade reduces coupling
- Layering

Structure



Structural Pattern: Facade

Consequences

- 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

Structural Pattern: Flyweight

Intent

- Use sharing to support large numbers of fine-grained objects efficiently

Motivation

- Document editor represents images, tables, etc by objects
- But not individual characters!
- Reason: high memory consumption
- Objects would provide more flexibility and uniform handling of components
- One *Flyweight Object* is shared among many “equal” characters

Structural Pattern: Flyweight

Motivation

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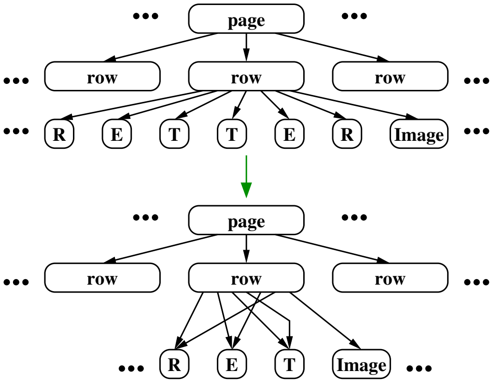
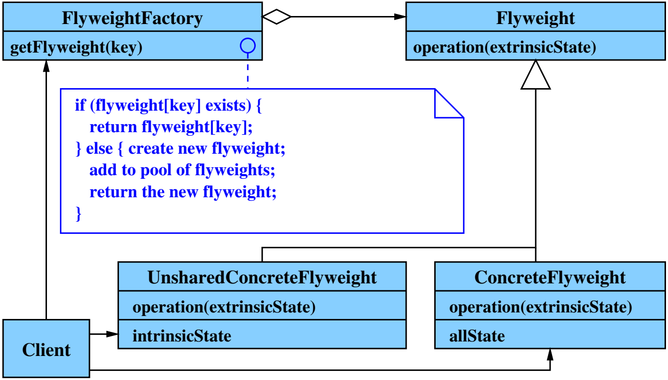


Structural Pattern: Flyweight

Structure



```
if (flyweight[key] exists) {
   return flyweight[key];
} else { create new flyweight;
   add to pool of flyweights;
   return the new flyweight;
}
```

Structural Pattern: Flyweight

Applicability

- Many similar objects
- Memory consumption to high for "full objects"
- State decomposable in intrinsic and extrinsic state
- Identity of objects does not matter

Consequences

- Decreased memory consumption
- Potentially increased time due to passing of extrinsic state

Behavioral Pattern: Observer

Intent

- Define 1 : *n*-dependency between objects
- State-change of one object notifies all dependent objects

Behavioral Pattern: Observer

Motivation

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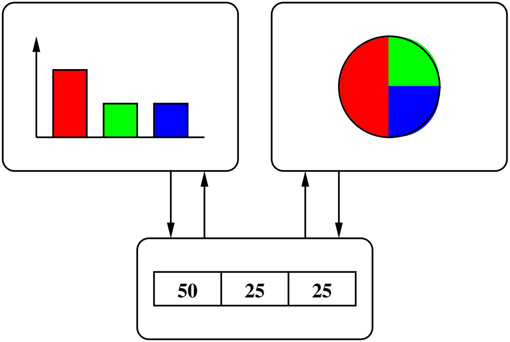
- Maintain consistency between internal model and external views



Behavioral Pattern: Observer

Structure

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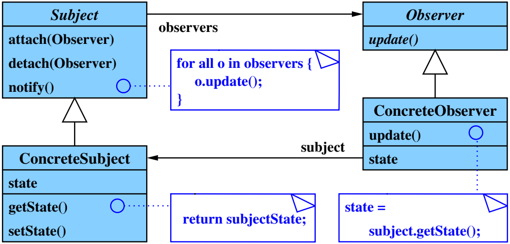


Subject

attach(Observer)

detach(Observer)

notify()

observers

for all o in observers {
o.update();
}

Observer

update()

ConcreteObserver

update()

state

subject

ConcreteSubject

state

getState()

setState()

return subjectState;

state =
subject.getState();

Behavioral Pattern: Observer

Applicability

- 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()`

Behavioral Pattern: Visitor

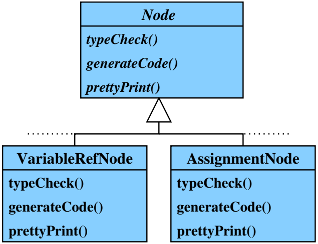
Intent

- Represents operations on an object structure by objects
- New operations without changing the classes

Behavioral Pattern: Visitor

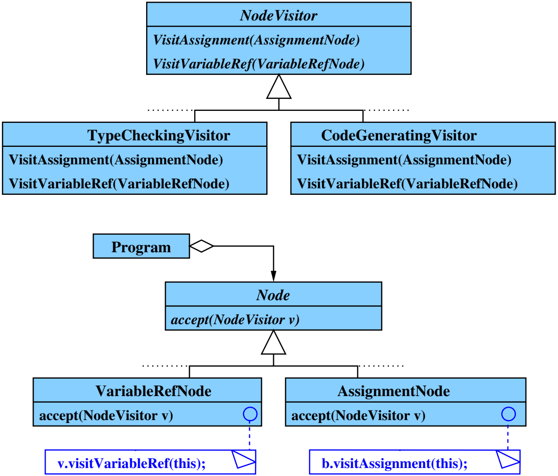
Motivation

- 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



Behavioral Pattern: Visitor

Syntax Tree with Visitors



Behavioral Pattern: Visitor

Structure

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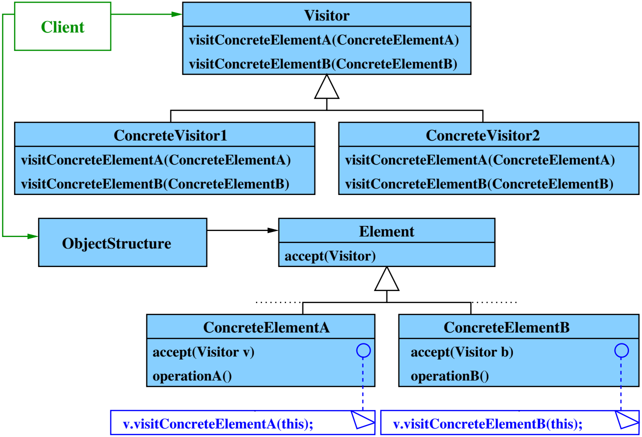

Client

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);

Behavioral Pattern: Visitor

Applicability

- 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

Behavioral Pattern: Iterator (Cursor)

Intent

- Sequential access to components of a container object
- Representation of object hidden

Behavioral Pattern: Iterator (Cursor)

Motivation

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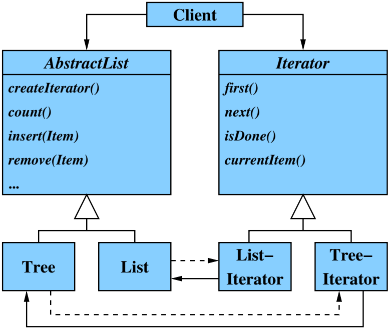
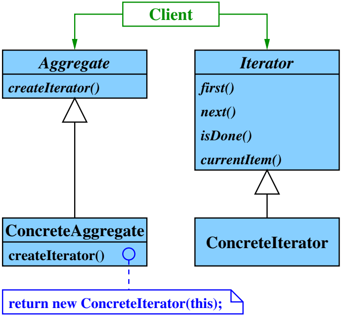


Behavioral Pattern: Iterator (Cursor)

Structure



- `ConcreteIterator` administers current object and determines subsequent object(s)

Behavioral Pattern: Iterator (Cursor)

Applicability

- Access objects “contents” without exposing representation
- Support multiple traversals
- Uniform interface for traversing different containers

Consequences

- Easy switching between different styles of traversal
- Simplifies `Aggregate`’s interface
- More than one pending traversal
- Control of iteration (internal vs. external)
- Traversal algorithm (Iterator vs. Aggregate)
- Robustness (are modifications visible?)