

# Design Patterns in OOAD

Following the “gang of four” (GoF)  
Gamma, Helm, Johnson, Vlissides, *Design Patterns*,  
Addison-Wesley 1995

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# Why Design Patterns?

- Apply well known and proven solutions
  - many problems are not new → no need to invent wheels
  - code structure easier to understand → easier maintenance
  - great help for beginners to learn good practice
  - patterns are not static, guide to individual solutions
- Analogies
  - song styles, theater pieces, novels, (architecture), engineering, ...

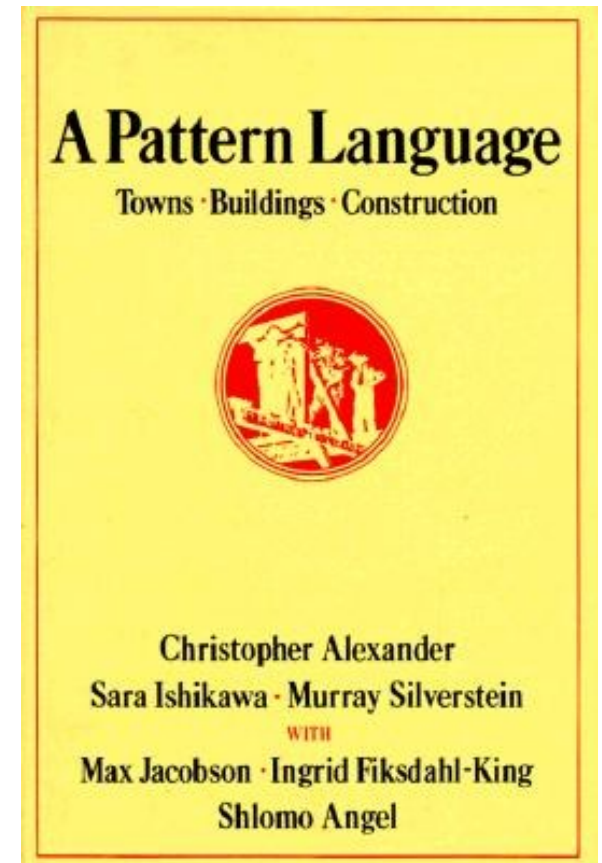
# History



C. Alexander (1936-), computer scientist and architect

Critical of traditional modern architecture, patterns as solution guides in architecture, incremental building, interaction with users, empower laypeople to create designs

Medieval cities built according to rules, not rigid masterplans



# Pattern Classification

|        | Creational                                               | Structural                                                                       | Behavioral                                                                                                                 |
|--------|----------------------------------------------------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| Class  | Factory Method*                                          | Adapter*                                                                         | Interpreter<br>Template Method*                                                                                            |
| Object | Abstract Factory*<br>Builder<br>Prototype*<br>Singleton* | Adapter*<br>Bridge<br>Composite*<br>Decorator *<br>Facade<br>Flyweight<br>Proxy* | Chain of Responsibility*<br>Command<br>Iterator*<br>Mediator*<br>Memento(*)<br>Observer*<br>State*<br>Strategy*<br>Visitor |

Not all patterns covered here, many more exist

# Patterns and OOAD

- Design patterns help to translate “OOD rules”
  - dependency management
  - components
  - code reuse
  - ease of planned (and unplanned) changes
  - maintenance
  - code quality

# Structured pattern description

- Pattern name
  - one- or two-word descriptive title
- Intent
  - what happens? Why? Design issue or problem?
- Motivation
  - example pattern application scenario
- Applicability
  - when to use? What problems solved?
- Structure
  - UML graphical description

# Structured pattern description

- Participants and Collaborations
  - classes, objects, their roles and collaborations
- Consequences and Implementation
  - results and trade-offs, implementation tricks
- Examples
  - code, projects
- Related patterns
  - relation to other patterns, combined uses

# Creational Patterns

- Organise object creation
- Class creational patterns
  - Factory Method
  - defer (part of) object creation to subclasses
- Object creational patterns
  - Abstract Factory
  - Singleton
  - defer (part of) object creation to other objects

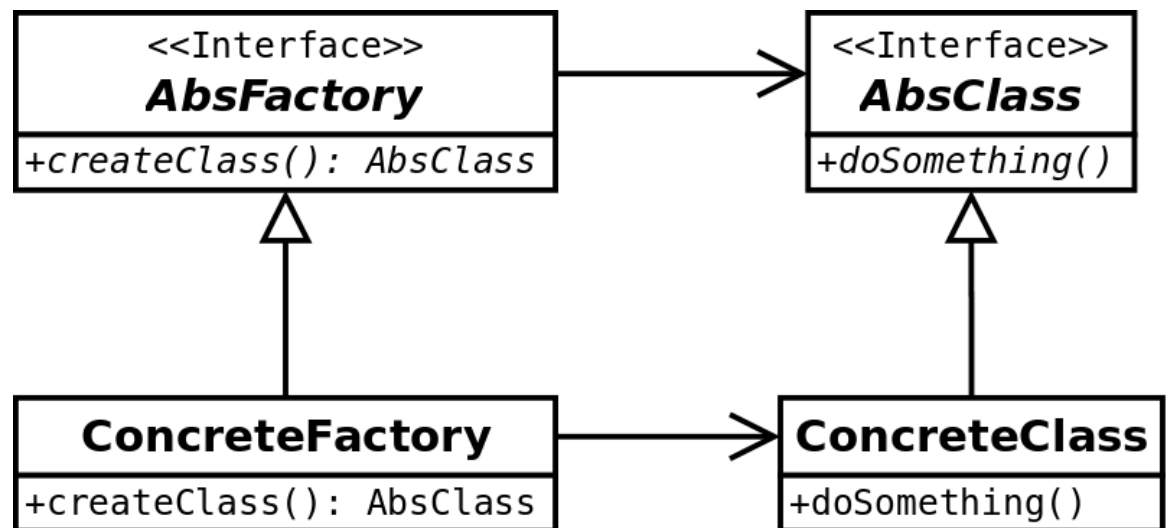
# (Abstract) Factory Method

Create objects without dependence on concrete classes

Isolate concrete classes from higher levels, createClass() is Factory Method, AbsFactory is Abstract Factory

Easy to replace functionalities

Hard to change class structure



GUIs on different platforms, plug-ins

Alternative: Prototype

# Prototype

Create new objects from a prototype through an interface to avoid dependency on concrete classes

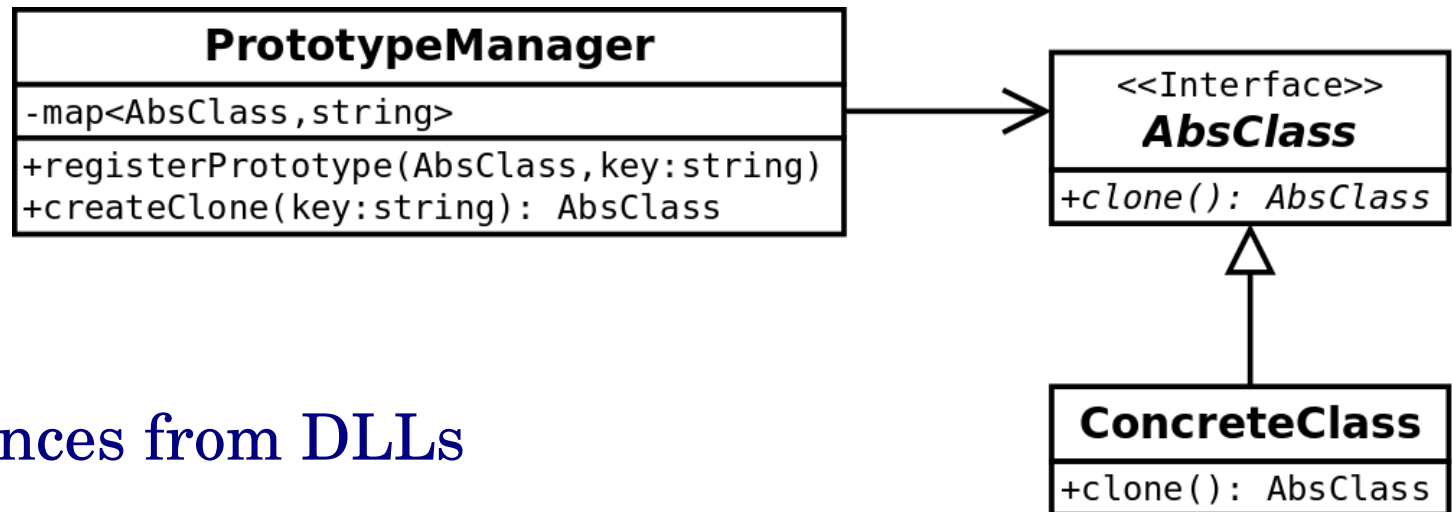
Isolate concrete classes from higher level

Avoid hierarchy of factories

Easy to get instances from DLLs

Classes must support cloning, must decide shallow or deep copy, take care of initialisation

Alternative: (Abstract) Factory method



# Singleton

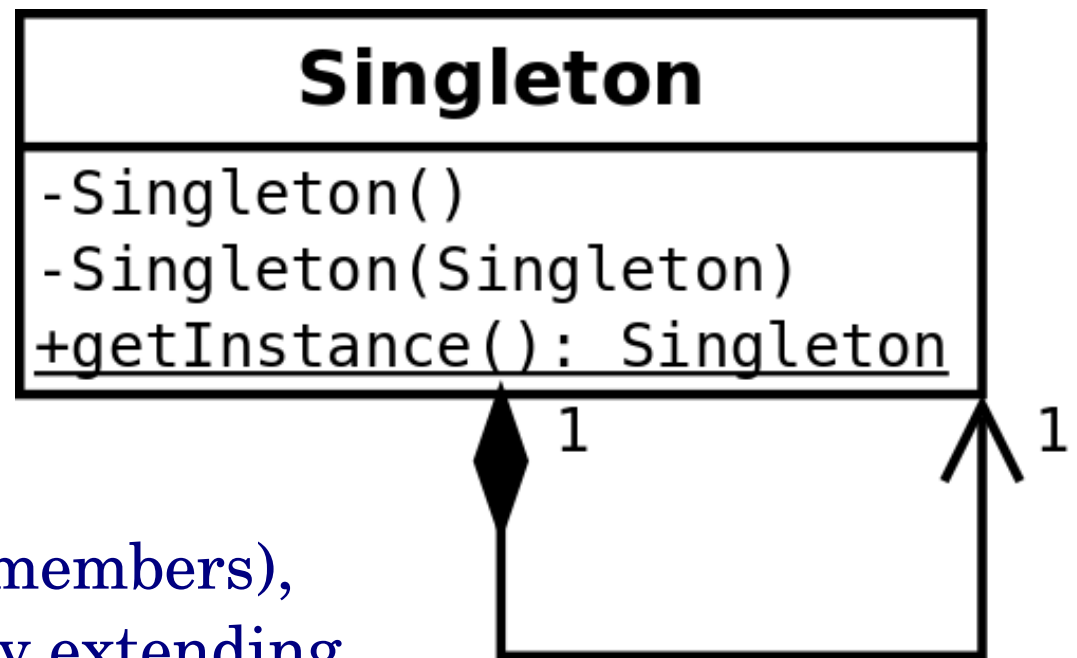
Guarantee that there is only one instance of a class

Avoid confusion over central objects

Private constructors, static method to return handle to single static instance

Can be subclassed (vs. static members), control number of instances by extending getInstance

Used in more complex patterns



# Structural Patterns

- Compose complex structures from small ones
- Class structural patterns
  - Compose interfaces or implementations using class inheritance
  - Adapter
- Object structural patterns
  - Compose objects to get new functionality, possibly at run-time
  - Adapter, Composite, Decorator, Proxy

# Adapter

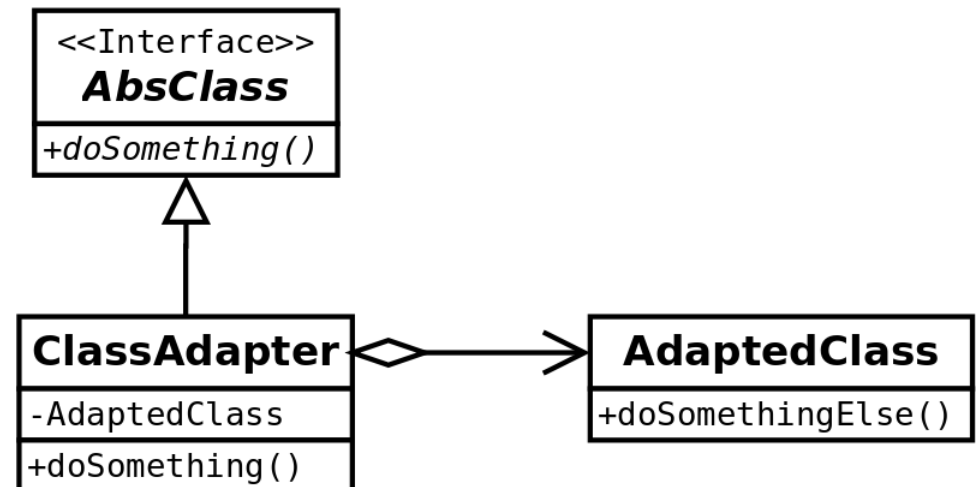
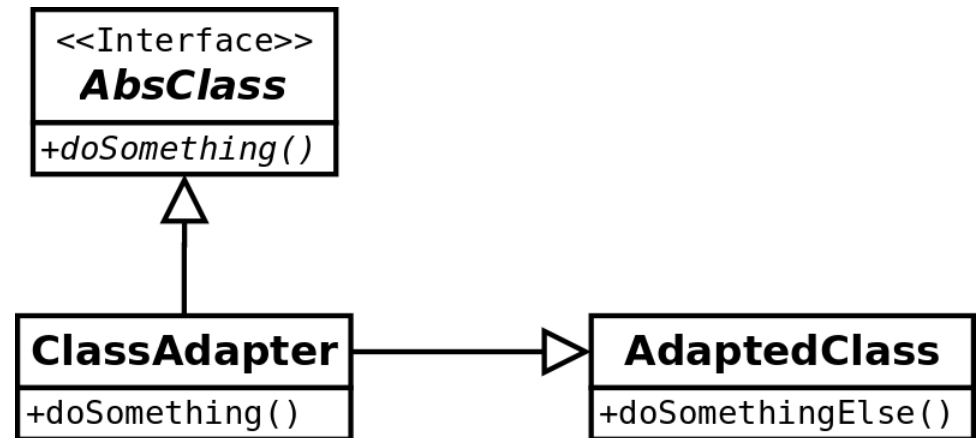
Convert (adapt) the interface of a class to interface expected by clients

Use existing class (libraries)

Class adapter: mult. inheritance, implement request using AdaptedClass methods

Object adapter: hold reference, forward or translate requests

Decorator, Proxy (no interface changes)



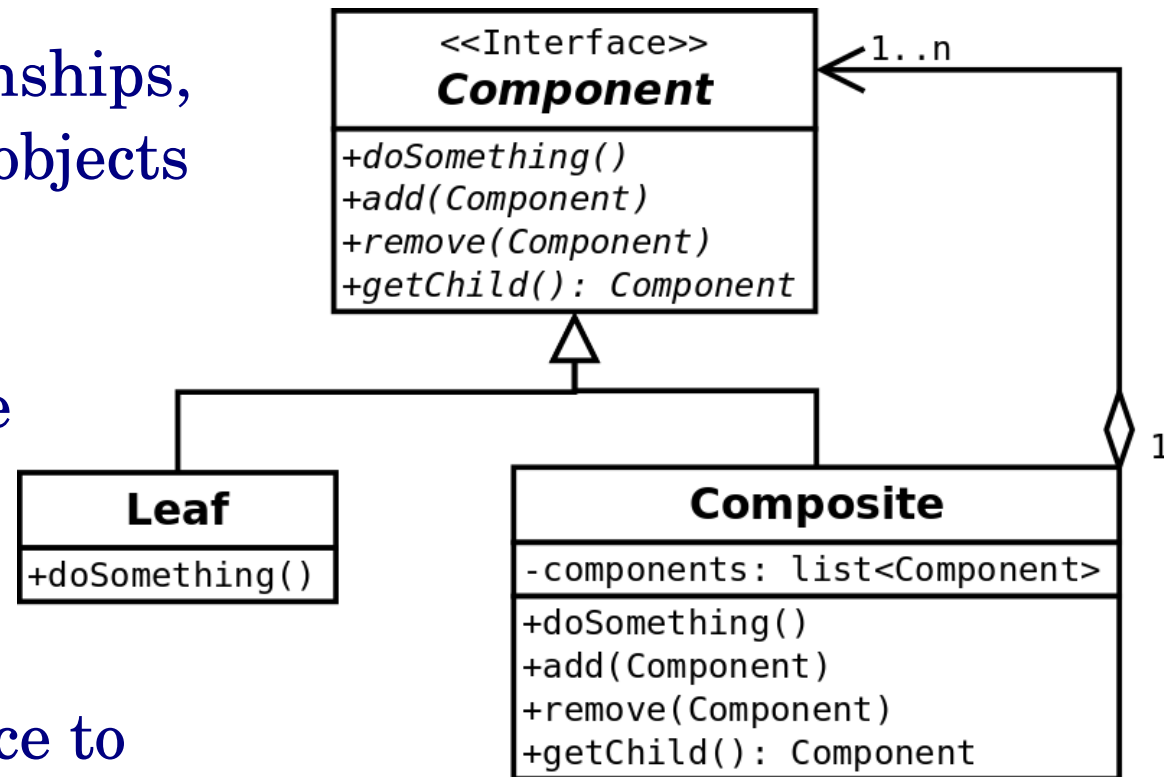
# Composite

Compose object recursively into tree-like structures

Represent whole-part relationships,  
handle objects and groups of objects  
uniformly

Composite can contain simple  
objects (Leaf) or composites

Clients can compose complex  
objects, but don't see difference to  
simple objects, easy to add new component  
types



Decorator, CoR, Iterator, Visitor can collaborate

# Decorator

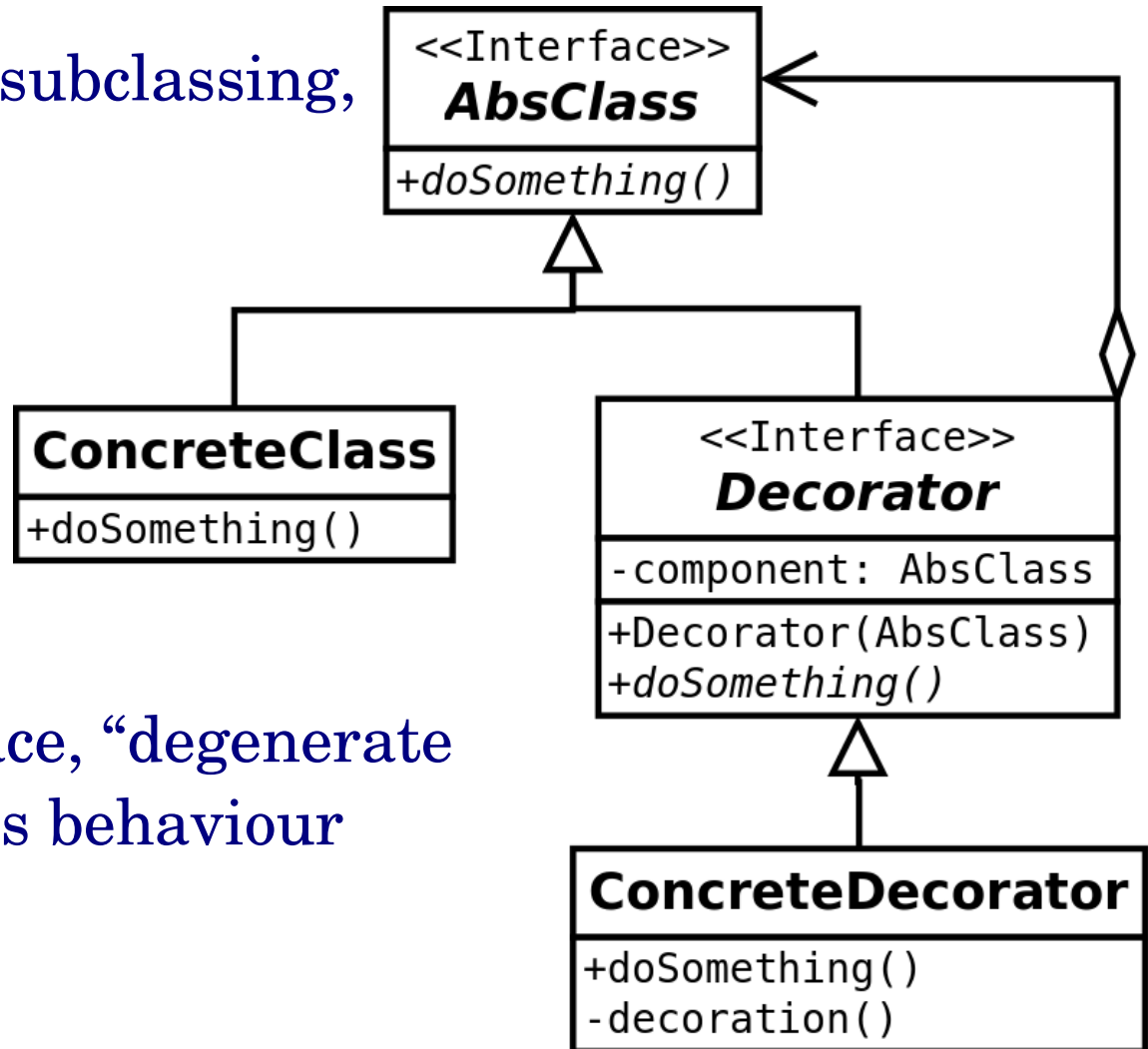
Add functionality dynamically to an object

Alternative to direct (static) subclassing,  
fight “combinatorics”

Decorator forwards requests  
to component

GUI toolkits, ...

Adapter also changes interface, “degenerate  
composite”, Strategy modifies behaviour



# Proxy

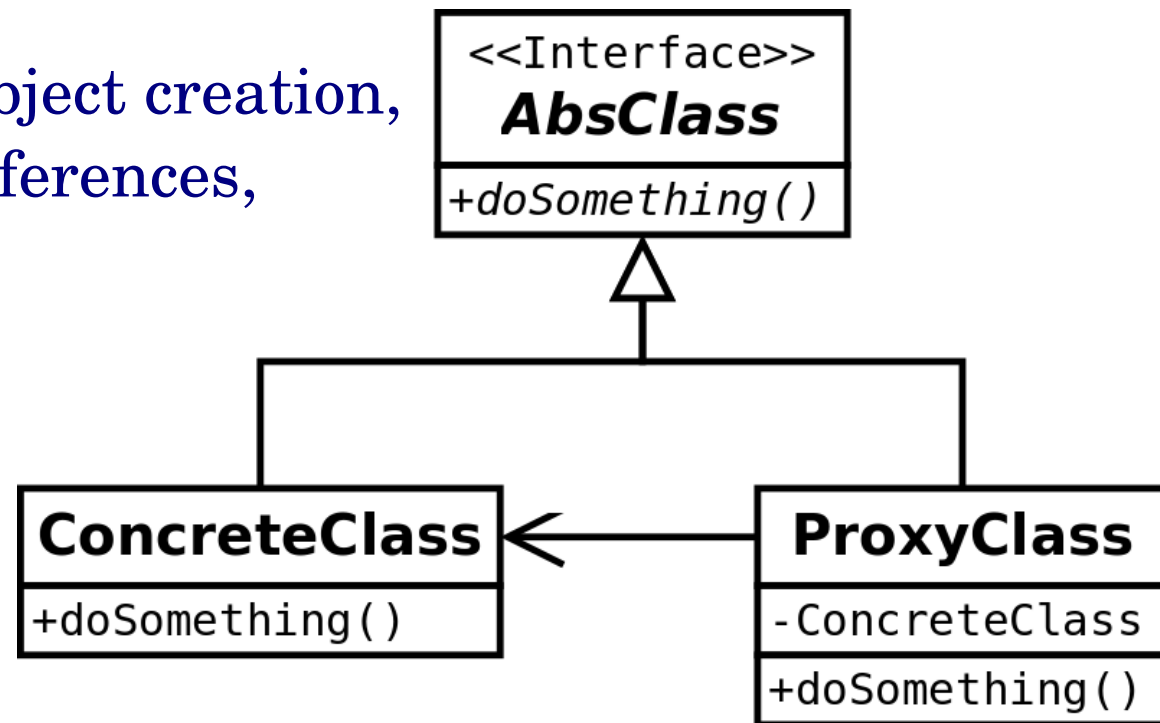
Provide placeholder for another object to control access

Support “lazy” operations (object creation, IO) and/or caching, smart references, “copy-on-write”

Client sees only ProxyClass objects, requests forwarded to ConcreteClass objects

Helps handling “expensive” objects

Proxy provides access control, Decorator or Adapter modify behavior or interface



# Behavioral Patterns

- Implement algorithms
- Class behavioral patterns
  - use inheritance to separate algorithm invariants from algorithm variants
  - Template Method
- Object behavioral patterns
  - use object composition to distribute algorithm parts (invariants, variants)
  - Chain of Responsibility, Iterator, State, Observer, Strategy

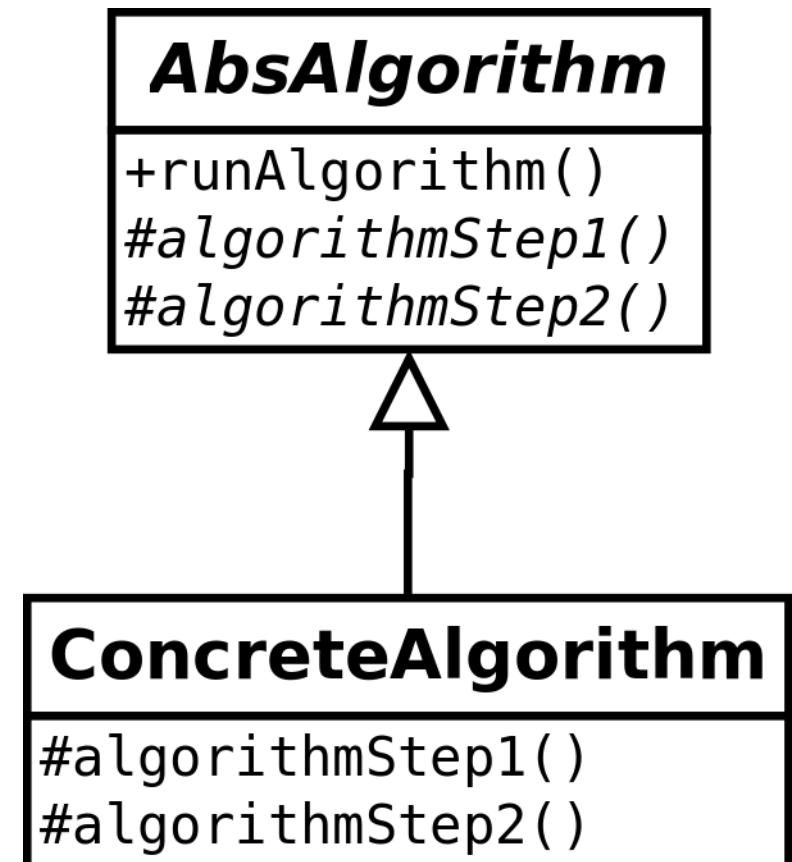
# Template Method

Define invariant algorithm skeleton and defer variant steps to methods in subclasses

Algorithm family implementation, localise common behavior of classes

Dependency inversion from concrete to abstract → class libraries

Factory Methods providing objects with algorithm steps often used in Template Method, Strategy gives algorithm variants at object level



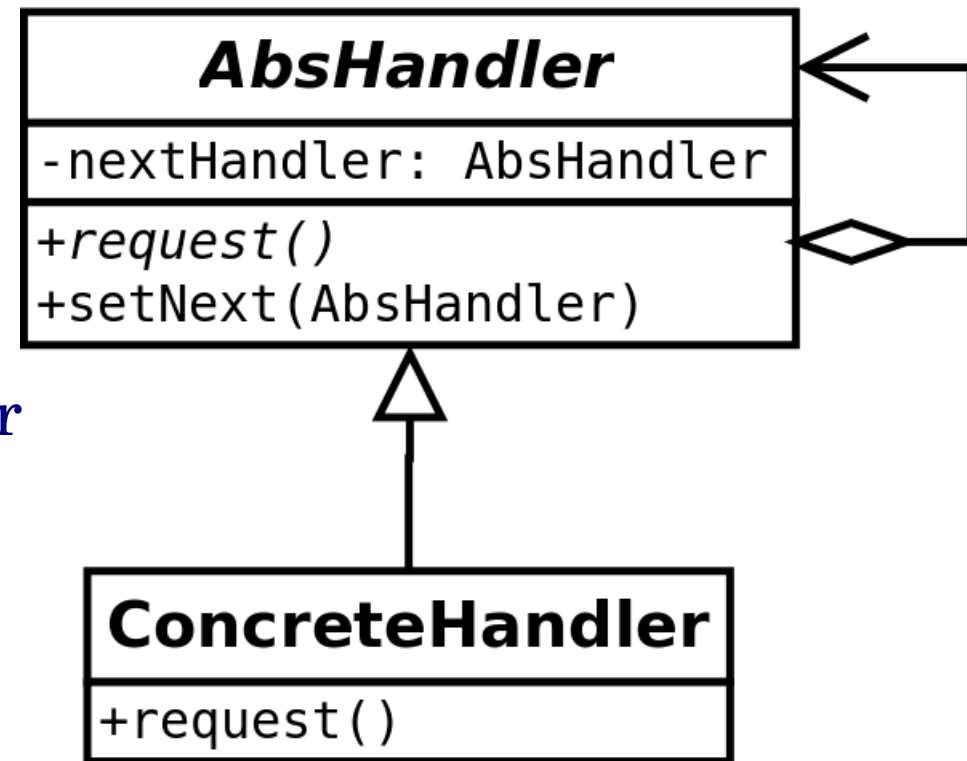
# Chain of Responsibility (CoR)

Allow several objects to handle a request by chaining them and passing the request along the chain, objects handle the request or pass it to the next object

In a dynamic system find correct object for a request

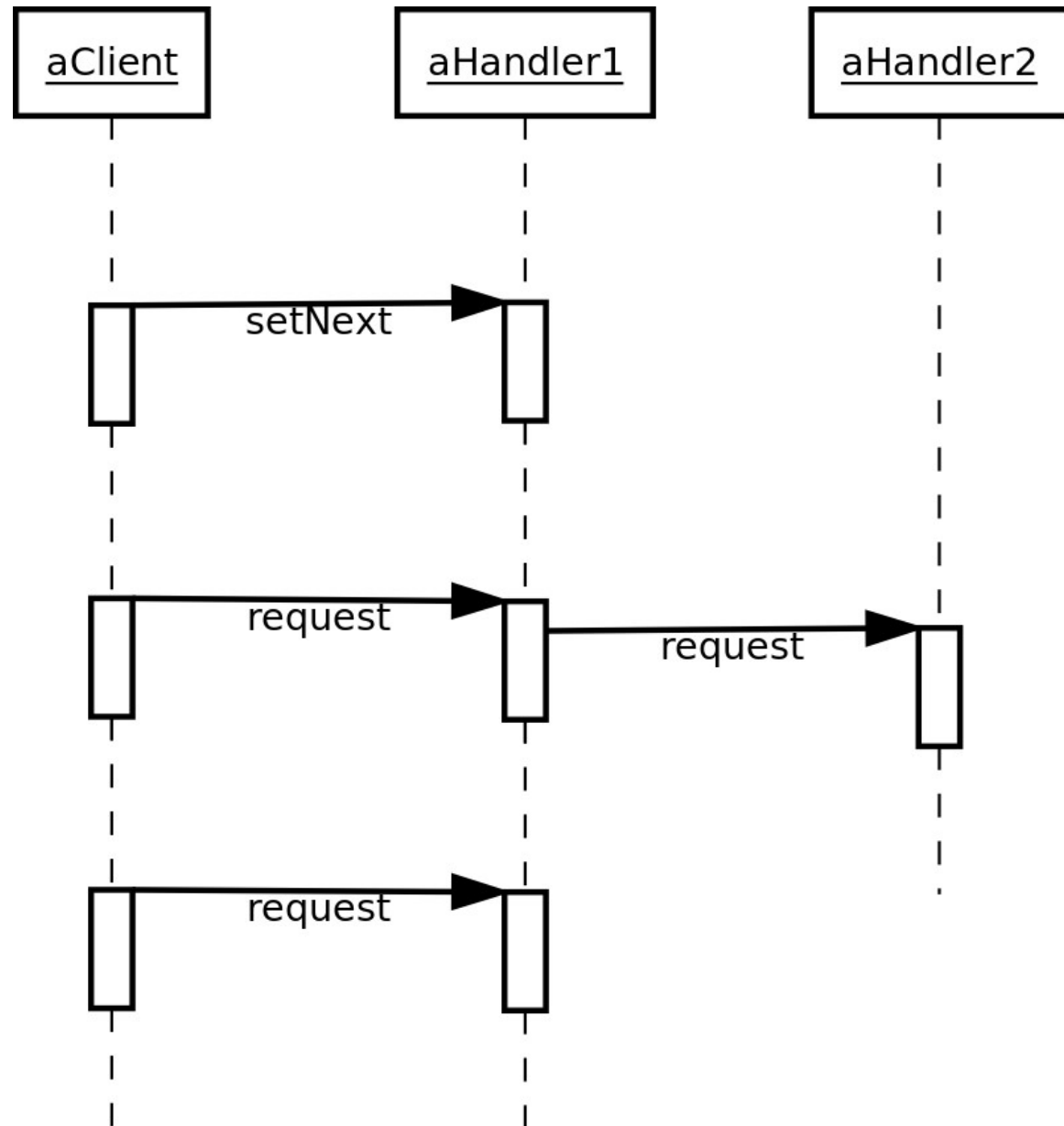
No direct connection between sender and receiver of request, can change request handling at run-time by reconfiguring the chain

Handle user events, collaboration with Composite where parent is next object, flexible procedures



# Chain of Responsibility

Object interaction  
diagram

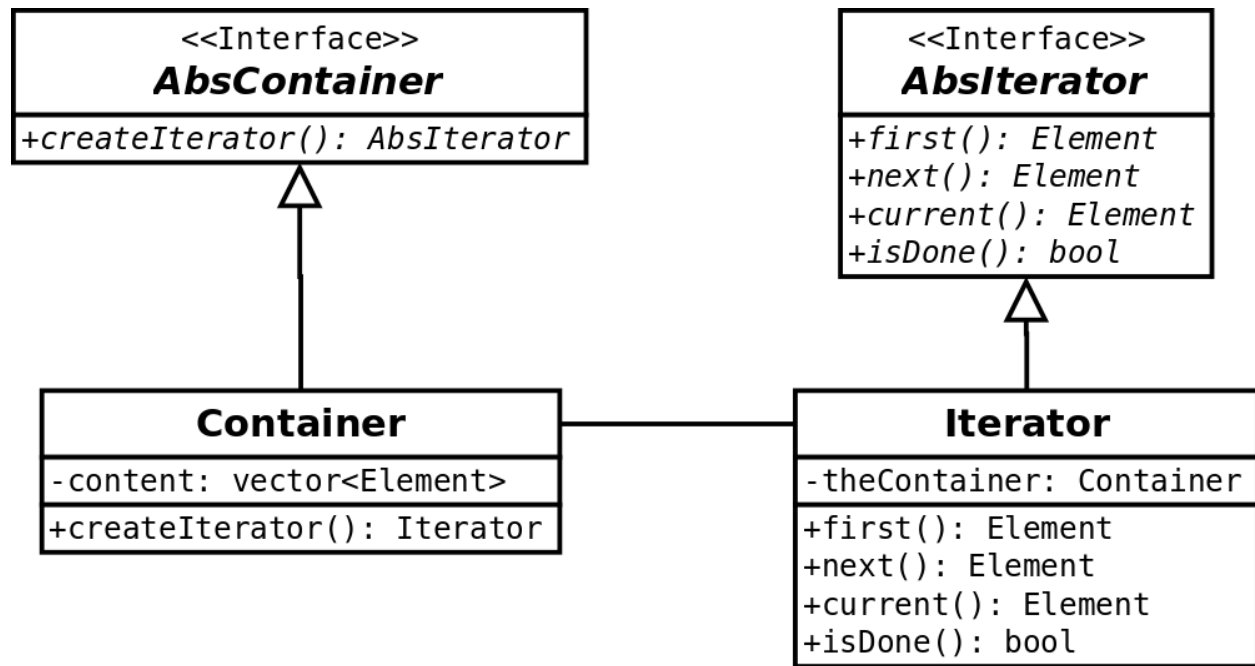


# Iterator

Access elements of a collection without exposing collection structure

Handle different collection structures, support heterogeneous collections, multiple traversals, different iteration algorithms

Container and Iterator tightly coupled, C++ with templates or interface+RTTI for elements

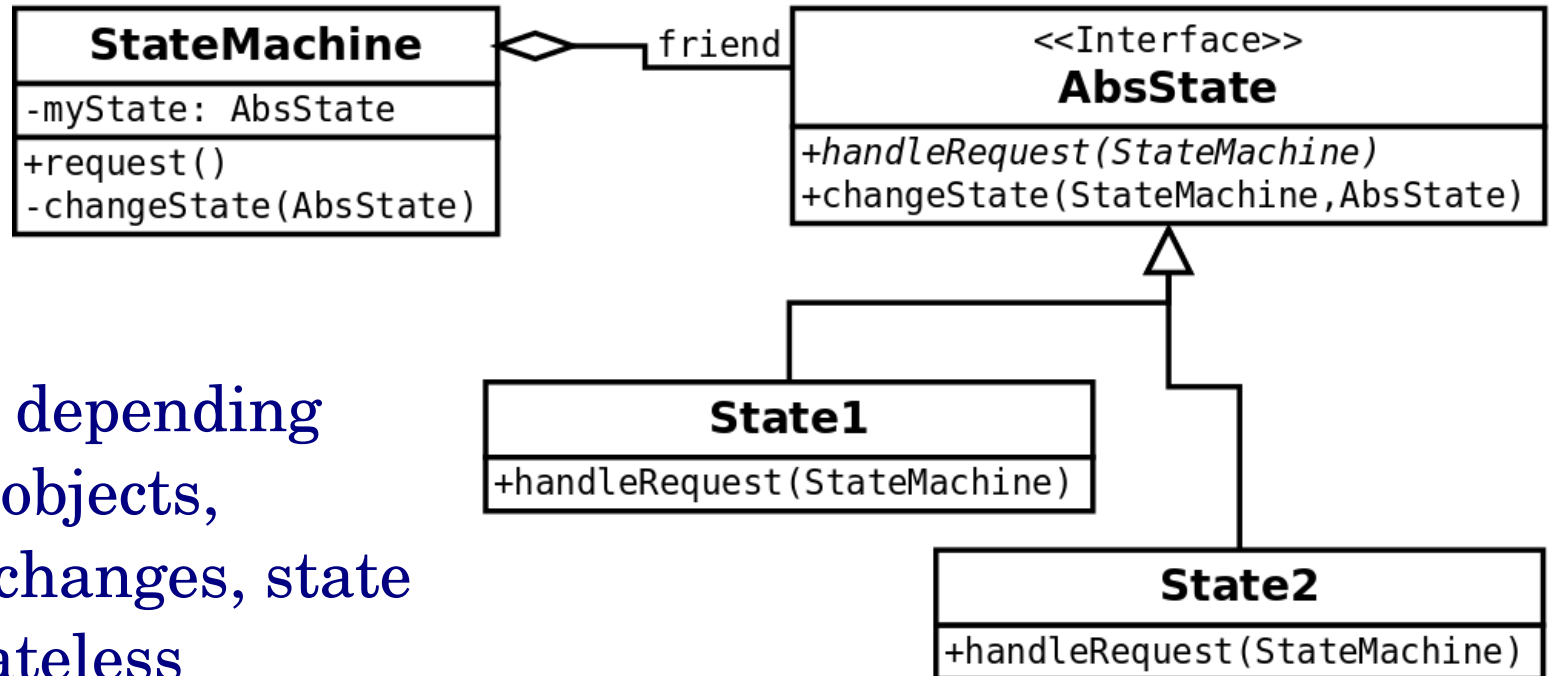


Iterator over Composite structures, Factory Method to create Iterators

# State

Allow object behavior change following state change

State machine modeling, refactoring of conditionals in methods depending on state

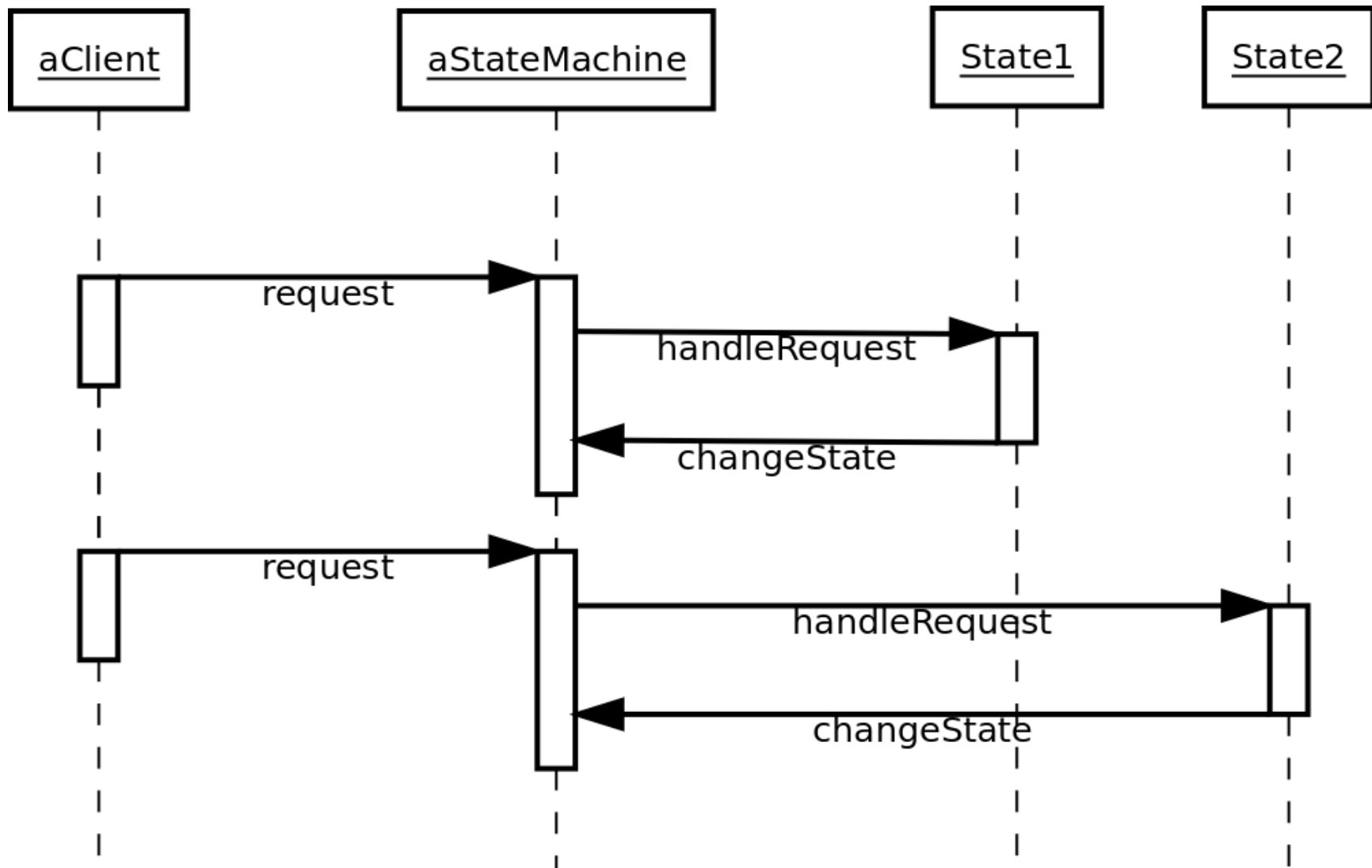


Localise state depending behavior into objects, explicit state changes, state objects are stateless

States can be Singletons

# State

## Object interaction diagram



# Observer

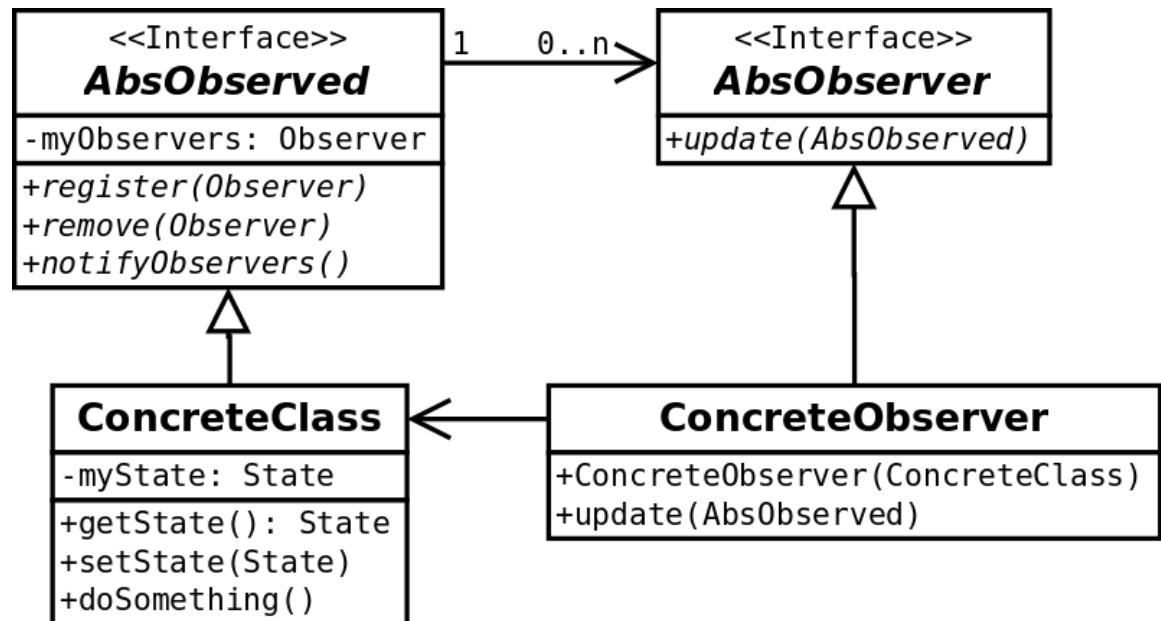
Define one-to-many relation between objects to notify clients when target changes state

“Broadcast” messages  
avoiding tight coupling  
of objects

Updates to observers can  
be unexpected

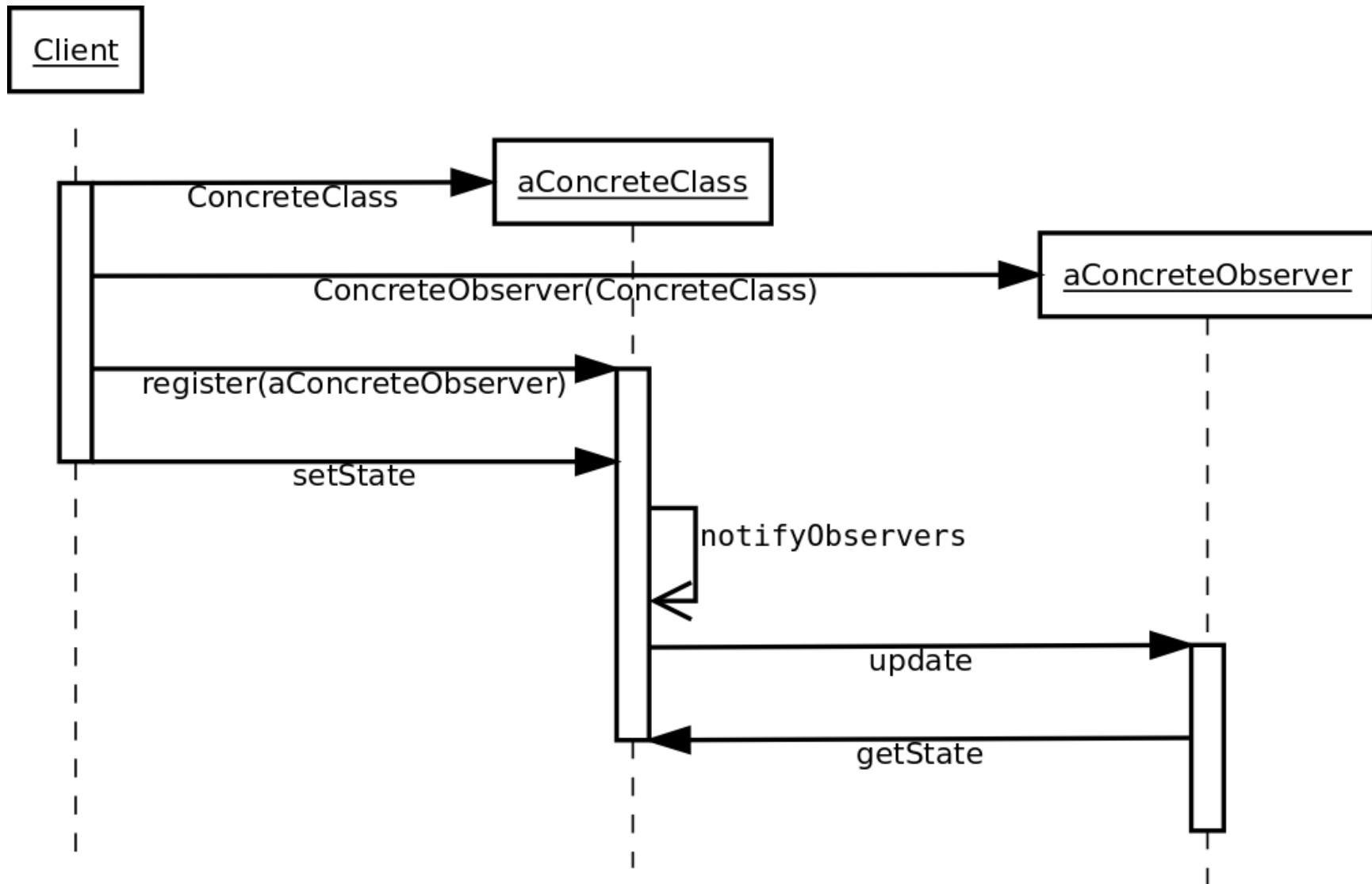
Complex relation between observed and observer objects can be collected into a “ChangeManager” object

GUI objects observe drawable objects for redrawing



# Observer

## Object interaction diagram



# Mediator

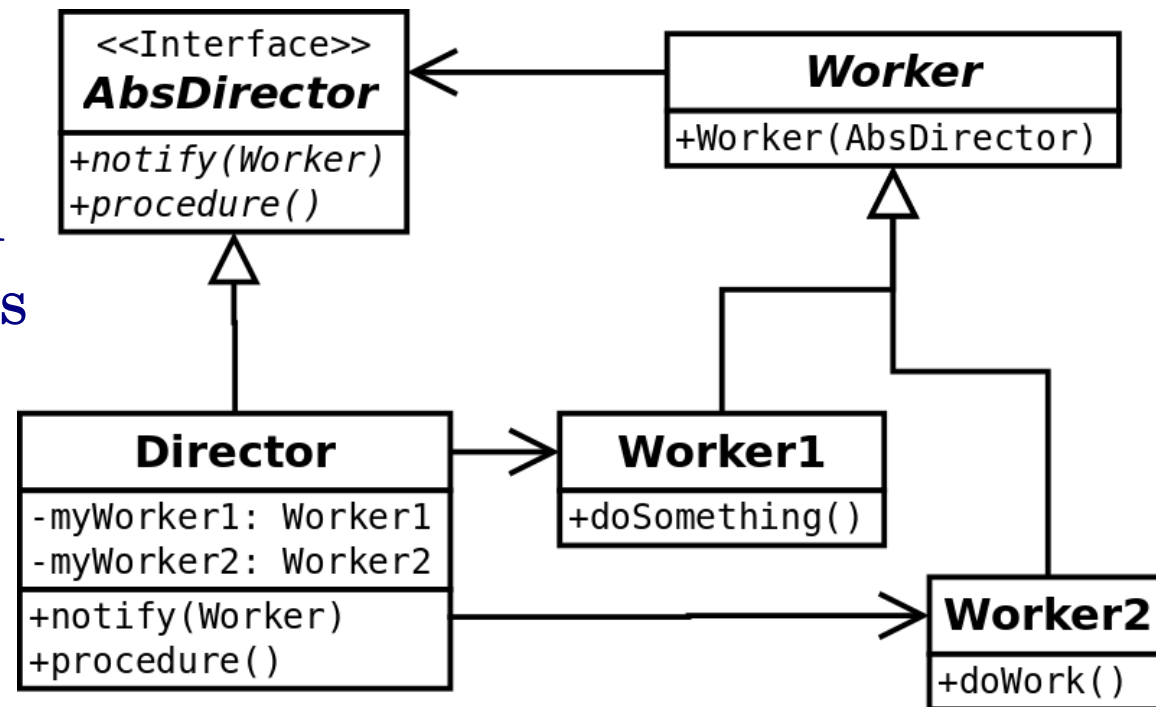
Enclose object interactions in a central “controller” object

Complex but well defined communication between objects,  
use when objects have links  
to many other objects

Worker notifies Director with  
its address, Director identifies  
and decides next step

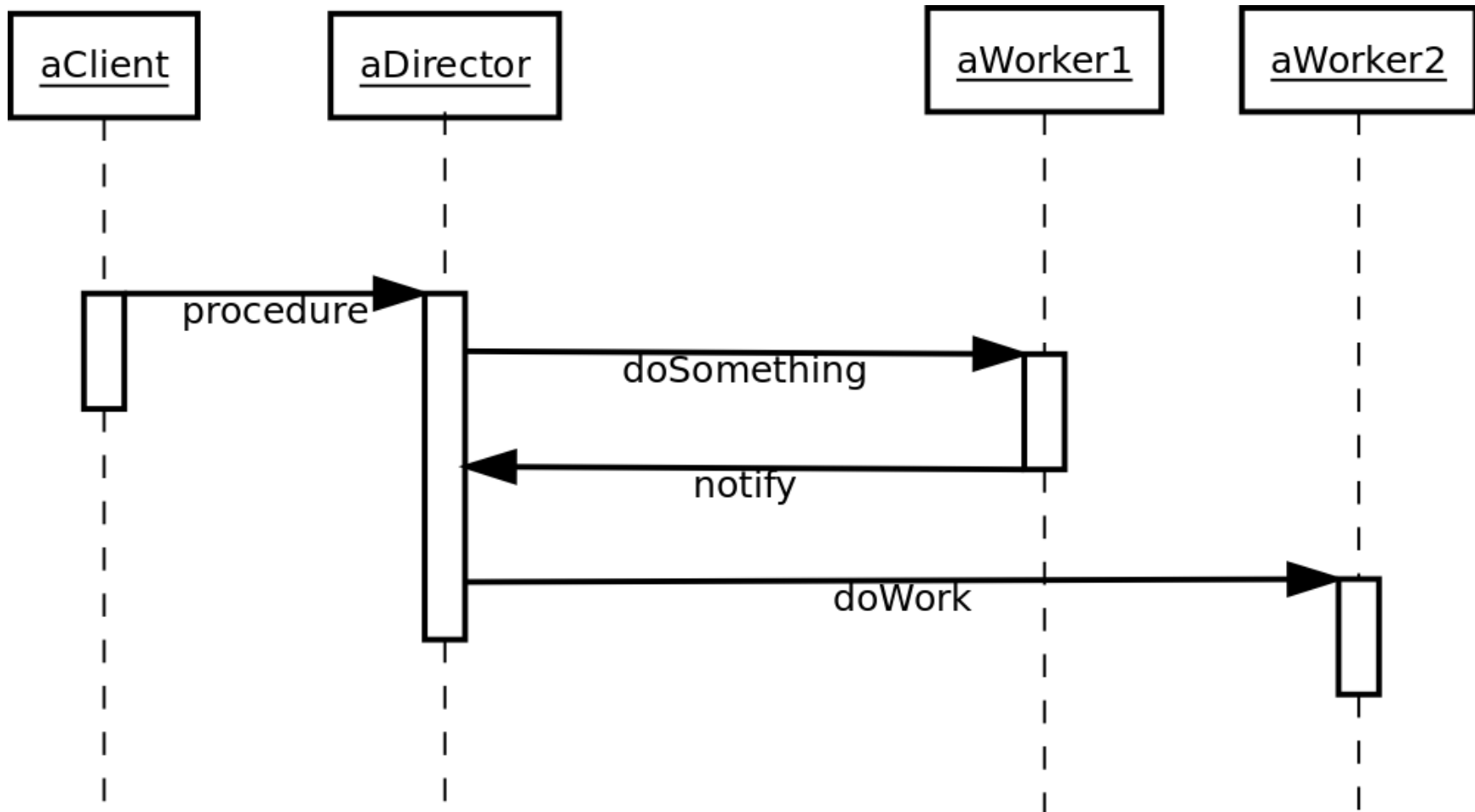
Decouple Workers, centralise  
control, can change protocol  
by subclassing Director

Director could be Observer of Workers



# Mediator

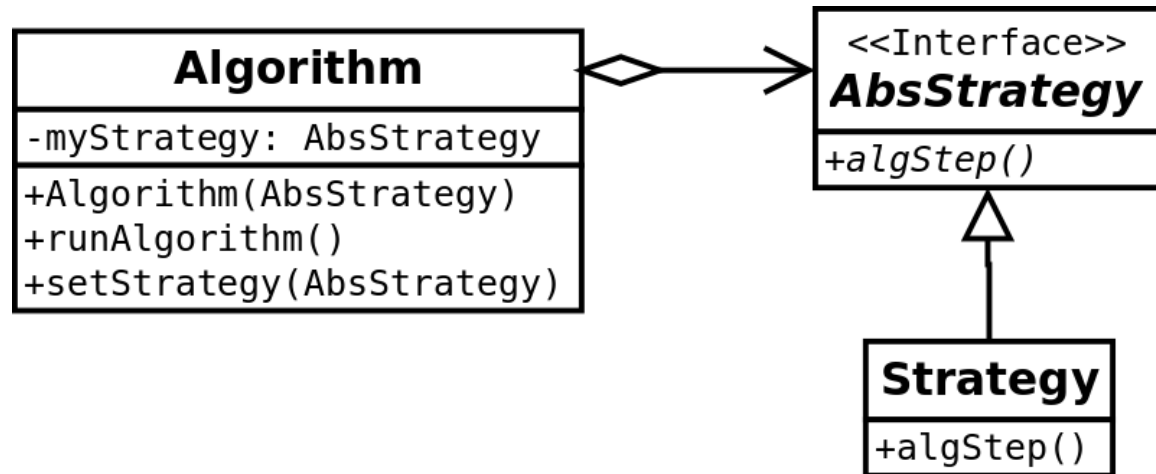
## Object interaction diagram



# Strategy

Define a family of algorithms interchangeable for clients

Make objects configurable for different behaviours,  
implement algorithm variants independent of invariants,  
hide details from clients  
via Strategy class, remove  
conditionals from Algorithm,  
different implementations  
of same behaviour



Track finding algorithm (pattern recognition, candidate selection, track fit)

# Summary and Discussion

- Creational
  - (Abstract) Factory Method vs Prototype
  - Only one object: Singleton
- Structural
  - Decorator: add behaviour
  - Composite: recursive object structures
  - Proxy: access control to other objects

# Summary and Discussion

- Behavioral
  - Template and Strategy: algorithm (in-) variants
  - State: state-dependent behavior
  - Iterator: access to complex object collections
  - CoR: communication to varying number of objects
  - Observer vs Mediator: object communication (de-)centralised

# Some HEP Patterns

- HEP offline programs have some special patterns
- Particular requirements
  - high throughput
  - variable algorithms
  - long lifetime of codes
  - programming interface for users

# Transient/Persistent (Memento)

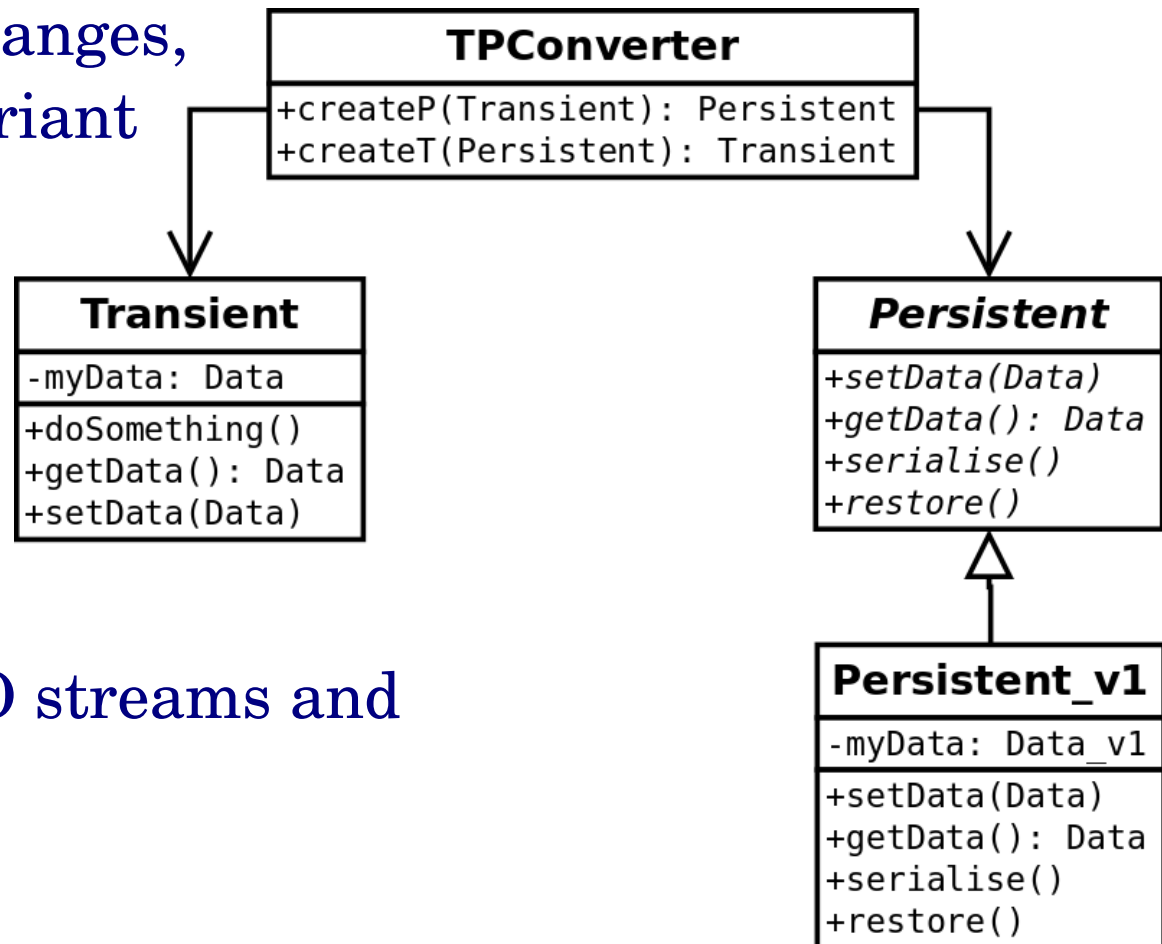
Decouple objects from the details of the storage system without violating data hiding

Storage systems subject to changes,  
keep other system parts invariant

Can replace storage system,  
Persistent and TPConverter

Memento w/o Converter

Use together with abstract IO streams and  
Blackboard



# Blackboard

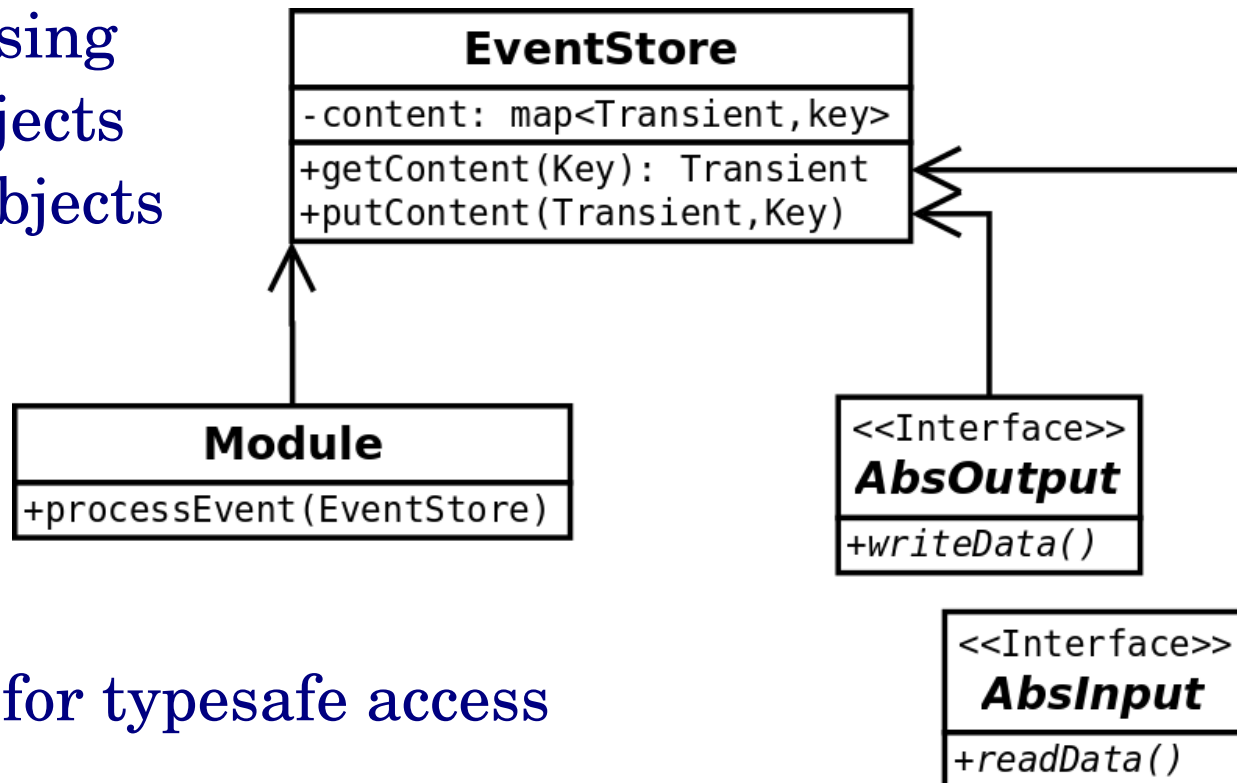
Model traditional HEP data processing with objects

EventStore is “COMMON BLOCK”  
to hold event data, processing  
Module gets Transient objects  
and puts new Transient objects

AbsInput and AbsOutput  
decouple the IO system  
from the data processing

C++ use template classes for typesafe access

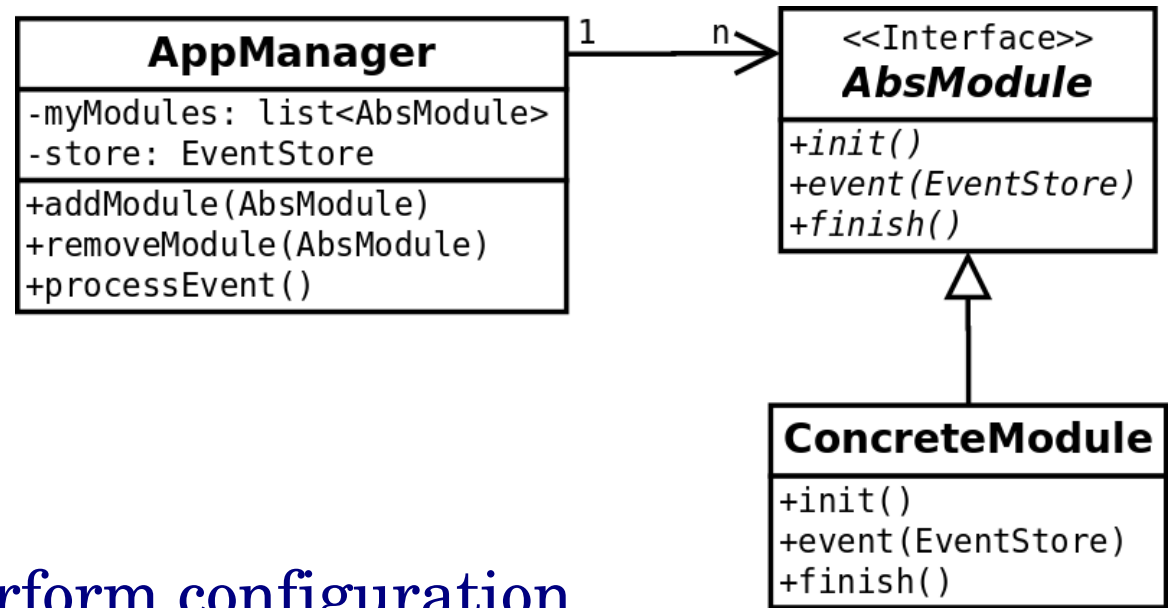
ATLAS “StoreGate”, BaBar “event”



# Procedure

Setup for configurable procedures for event data processing

Establish framework for  
Flexible data processing  
procedures with stable  
IO structure



Often combined with script  
language (tcl, python) to perform configuration

ATLAS athena (Gaudi), BaBar offline sw, ...

Mediator without callback to Director