1 Introduction

1.1 Pattern Definition

- Descriptions of successful engineering stories
- Address recurring problem
- Descripe generic solution that worked
- Tell about the forces of the problem (why is the problem hard)
- Tell about the engineering trade-offs to take (Benefits / Liabilities)
- Solution (Implementation)

1.2 Type of Patterns

- Architecture Patterns (Waiting Room)
- Software Patterns
  - Design Pattern (Elements of Reusable Object-Oriented Sofware)
  - Pattern-oriented Software Architecture (POSA)
- Organizational Patterns
- Learning and Teaching Patterns
- Documentation Patterns

1.3 Pattern Formats

1.3.1 POSA

- Pattern name
- Intent
- Problem
- Solution
- Benefits / Liabilities

1.3.2 Fault Tolerance

- Name
- Intent
- Solution
- Benefits / Liabilities

1.3.3 MAPI

- Name
- Intent
- Consequences

1.3.4 Game Programming Patterns

- Name
- Problem
- Engineering Story that worked
- Benefits / Liabilities
- Solution

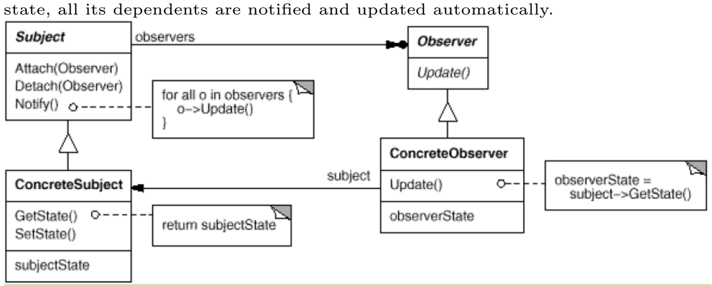
1.4 What are Patterns not?

- Silver bullet
- Novices Tool
- Ready Made Components
- Means to turn off your brain

2 GoF Patterns

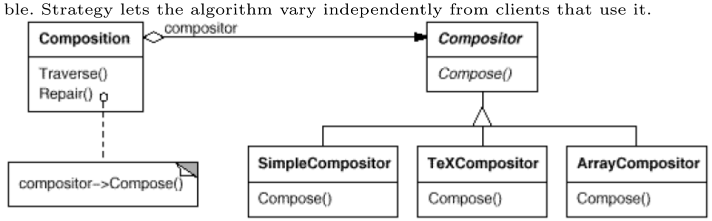
2.1 Observer

Define a one-to-many dependency between objects so that when one object changes state, all its dependents are notified and updated automatically.



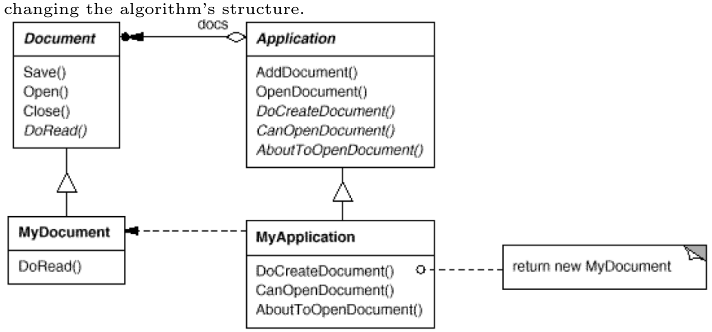
2.2 Strategy

Define a family of algorithms, encapsulate each one, and make them interchangeable. Strategy lets the algorithm vary independently from clients that use it.



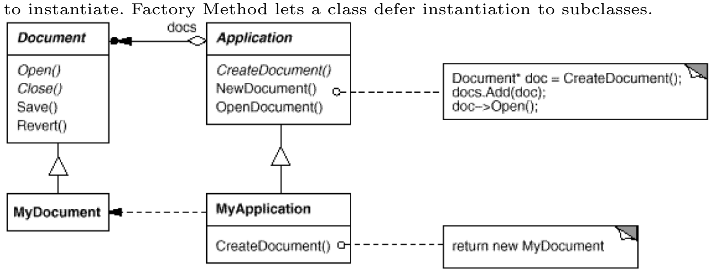
2.3 Template Method

Define the skeleton of an algorithm in an operation, deferring some steps to subclasses. Template Method lets subclasses redefine certain steps of an algorithm without changing the algorithm's structure.



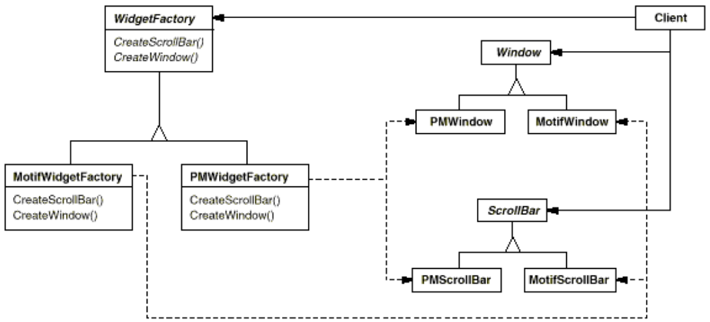
2.4 Factory Method

Define an interface for creating an object, but let the subclass decide which class to instantiate. Factory Method lets a class defer instantiation to subclasses.



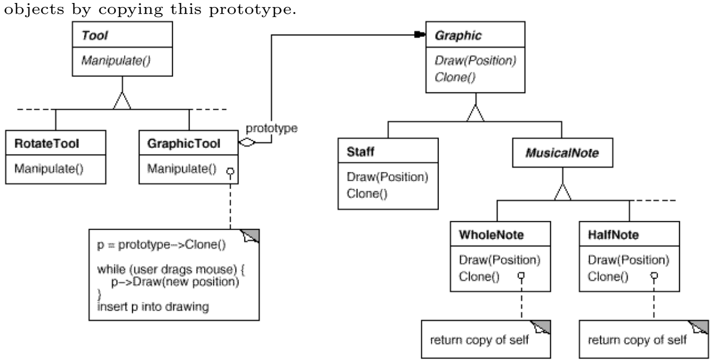
2.5 Abstract Factory

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



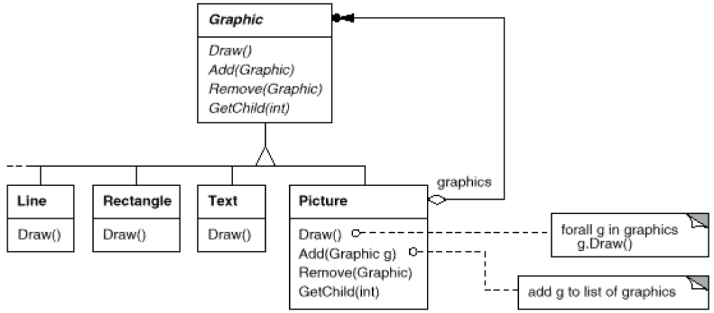
2.6 Prototype

Specify the kinds of objects to create using a prototypical instance, and create new objects by copying this prototype.



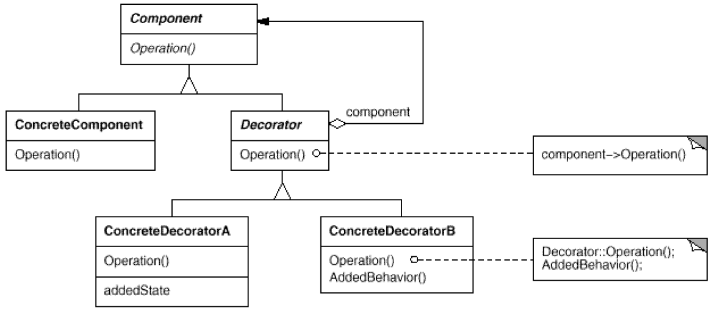
2.7 Composite

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



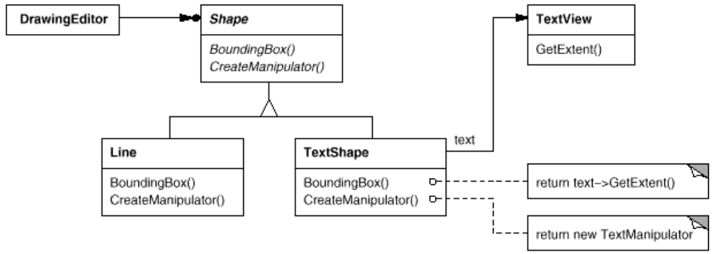
2.8 Decorator

Attach additional responsibilities to an object dynamically. Decorators provide a flexible alternative to subclassing for extending functionality.



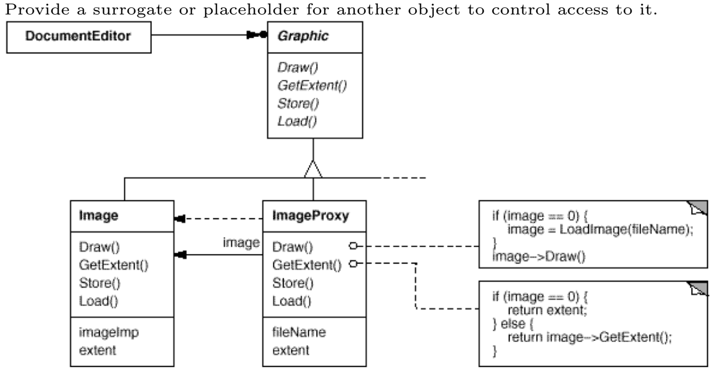
2.9 Adapter

Convert the interface of a class into another interface clients expect. Adapter lets classes work together that couldn't otherwise because of incompatible interfaces.



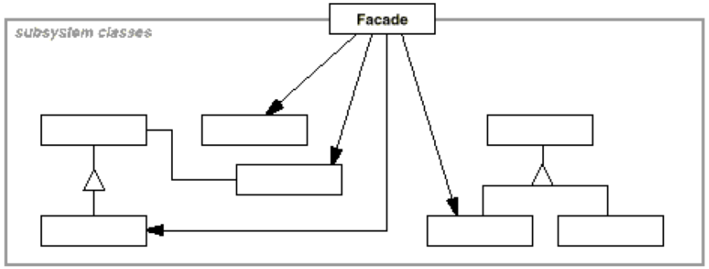
2.10 Proxy

Provide a surrogate or placeholder for another object to control access to it.



2.11 Facade

Provide a unified interface to a set of interfaces in a subsystem. Facade defines a higher-level interface that makes the subsystem easier to use.



2.12 Mediator

2.12.1 Problem

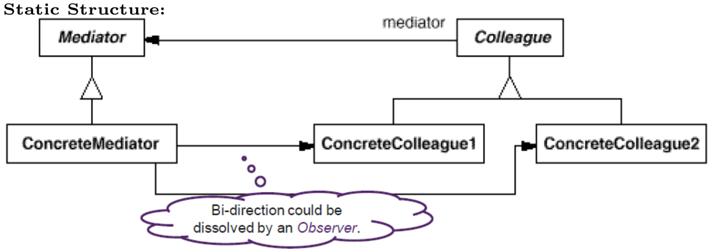
- Object Structures may result in many connections between objects
- In the worst case, every object ends up knowing about every other

Intent:

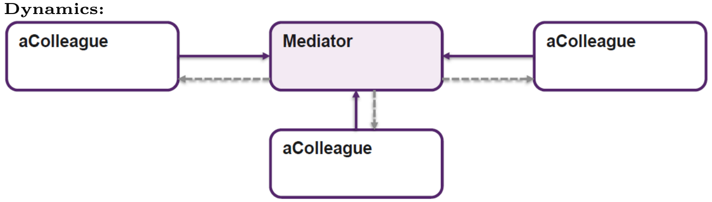
- How can strong coupling between multiple objects be avoided and communication simplified?

2.12.2 Solution

Define an object that encapsulates how a set of objects interact. Mediator promotes loose coupling by keeping objects from referring to each other explicitly, and lets you vary their interaction independently.
Mediator: Encapsulates how a set of objects interact
Colleaues: Refer to Mediator; this promotes loose coupling
Static Structure:



Dynamics:



2.12.3 Implementation

- Mediator as an Observer
- Colleagues act as Subject

Known Uses:

- Message Bus Systems
- Redux Dispatcher

2.12.4 Summary

Benefits:

- Colleague classes may become more reusable, low coupling
- Centralizes control of communication between objects
- Encapsulates protocols

Liabilities:

- Adds complexity
- Single point of failure
- Limits subclassing (of mediator class)
- May result in hard maintainable monoliths

2.13 Memento

2.13.1 Problem

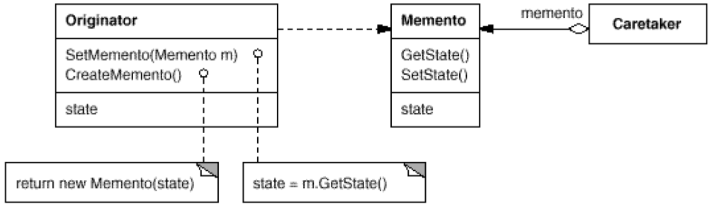
- Sometimes it's necessary to record the internal state of an object
- Objects normally encapsulate their state, making it inaccessible

Intent:

- How can the state of an object be externalized without violating its encapsulation?

2.13.2 Solution

Without violating encapsulation, capture and externalize an objects internal state so that the object can be restored to this state later.



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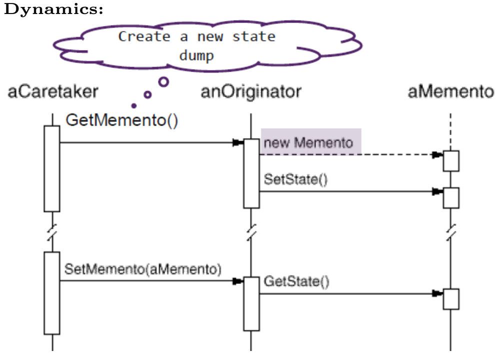


2.13.3 Participants

Memento

- Stores some / all the internal state of the Originator
- Allows only the originator to access its internal information

Originator

- Can create Memento objects to store its internal state at strategic points
- Can restore own state to what the Memento object dictates

Caretaker

- Stores the Memento objects
- Cannot explore / operate the contents

2.13.4 Implementation

- Originator creates memento and passes over its internal state
- Can be combined with Factory Method
- Declare Originator as *friend* of Memento, so Originator can read out its properties

2.13.5 Summary

Benefits

- Internal State of an object can be saved and restored at any time
- Encapsulation of attributes is not harmed
- State of objects can be restored later

Liabilities

- Creates a complete copy of the object every time, no diffs (memory usage)
- No direct access to saved state, it must be restored first

2.14 Command

2.14.1 Problem

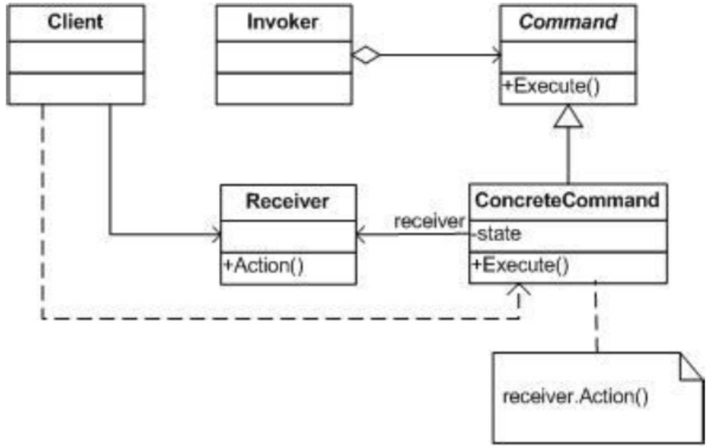
- Decouple the decision of what to execute from the decision of when to execute
- The execution needs an additional parametrization context

Intent:

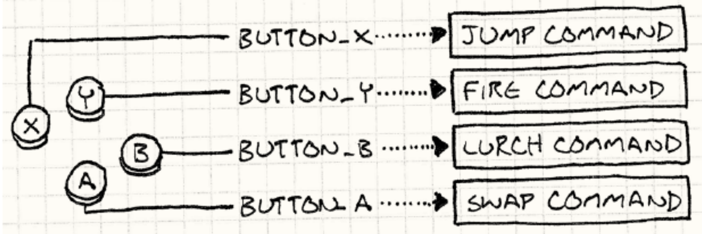
- How can commands be encapsulated, so that they can be parameterized, scheduled, logged and/or undone?

2.14.2 Solution

Encapsulate a request as an object, thereby letting you parameterize clients with different requests, queue or log requests, and support undoable operation.



Dynamics:



2.14.3 Summary

Benefits:

- The same command can be activated from different objects
- New commands can be introduced quickly and easily
- Command objects can be saved in a command history
- Provides inversion of control, encourages decoupling in both time and space

Liabilities:

- Large designs with many commands can introduce many small command classes mauling the design

2.15 Command Processor

2.15.1 Problem

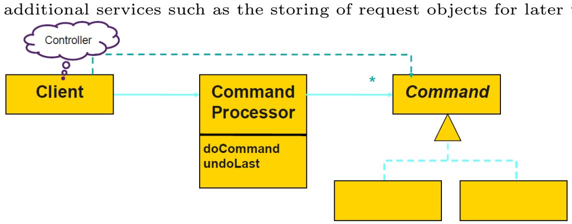
- Common UI applications support do and multiple undo steps
- Steps forward and backward are accessible in a history

Intent:

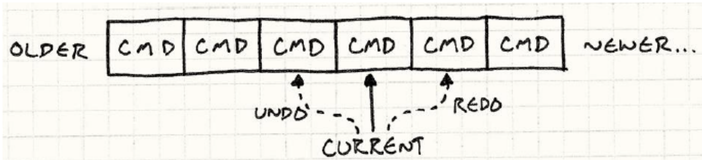
- How could we manage command objects, so the execution is seperated from the request and the execution can be undone later?

2.15.2 Solution

Separate the request for a service from its execution. A command processor component manages requests as separate objects, schedules their execution, and provides additional services such as the storing of request objects for later undo.



Dynamics:



2.15.3 Participants

Command Processor

- A Separate processor object can handle the responsibility for multiple Command objects

Command

- A uniform interface to execute functions

Controller

- Translates requests into commands and transfers commands to Command Processor.

2.15.4 Implementation

- Command Processor contains a *Stack* which holds the command history
- Controller creates the Commands and passes them over to Command Processor
- Creation of Commands may be delegated to a *Simple Factory*

2.15.5 Summary

Benefits:

- Flexibility
- Allows addition of services related to command execution
- Enhances testability

Liabilities:

- Efficiency loss due additional indirection

2.16 Visitor

2.16.1 Problem

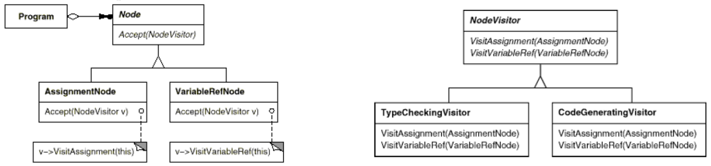
- Operations on specific classes needs to be changed/added without needing to modify these classes
- Different algorithms needed to process an object tree

Intent:

- How can the behaviour on individual elements of a data structure be changed/replaced whout changing the elements?

2.16.2 Solution

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



2.16.3 Implementation

- 2 Class Hierarchies (Elements / Visitors)
- Visitors iterate though object hierarchy
- Solves Double-Dispatch problem of single dispatched programming languages

Patterns that combine naturally with Vistor:

- Composite
- Interpreter
- Chain of Responsibility

2.16.4 Summary

Benefits:

- Visitor makes adding new operatios easy
- Separates related operations from unrelated ones

Liabilities:

- Adding new node classes is hard
- Visiting sequence fix defined within nodes
- Visitor breaks logic apart

3 Beyond GoF

3.1 External Iterator

3.1.1 Problem

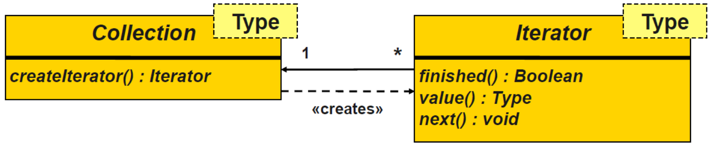
- Iteration through a collection depends on the target implementation
- Separate logic of iteration into an object to allow multiple iteration strategies

Intent:

- How can strong coupling between iteration and collection be avoided, generalized and provided in a collection-optimized manner?

3.1.2 Solution

Provide a way to access the elements of an aggregate object sequentially without exposing its underlying representation.



Elementary operations of an Iterator's behaviour:

- Initializing an iteration *new ArrayList().iterator();*
- Checking a completion condition *it.hasNext();*
- Accessing a current target value *var x = it.next();*
- Moving to the next target value *it.next();*

3.1.3 Summary

Benefits:

- Provides a single interface to loop though any kind of collection

Liabilities:

- Multiple iterators may loop through a collection at the same time
- Life-Cycle Management of iterator objects
- Close coupling between Iterator and Collection class
- Indexing might be more intuitive for programmers

3.2 Enumeration Method

3.2.1 Problem:

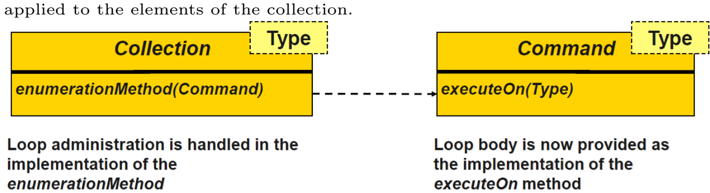
- Iteration management is performed by the collection's user
- Avoid state management between collection and iteration

Intent:

- How can a collection be iterated considering the collection state and furthermore state management be reduced?

3.2.2 Solution

Support encapsulated iteration over a collection by placing responsibility for iteration in a method on the collection. The method takes a Command object that is applied to the elements of the collection.



3.2.3 Summary

Programming languages already implement Enumeration Method as their loop construct. (e.g. *.forEach()*)

Benefits:

- Client is not responsible for loop housekeeping details
- Synchronization can be provided at the level of the whole traversal rather than for each element access

Liabilities:

- Functional approach, more complex syntax needed
- Often considered too abstract for programmers

3.3 Batch Method

3.3.1 Problem

- Collection and client (iterator user) are not on the same machine
- Operation invocations are no longer trivial

Intent:

- How can a collection be iterated over multiple tiers without spending far more time in communication than in computation?

3.3.2 Solution

Group multiple collection accesses together to reduce the cost of multiple individual accesses in a distributed environment.

- Define a data structure which groups interface calls on client side
- Provide an interface on servant to access groups of elements at once

3.4 Objects for State

3.4.1 Problem

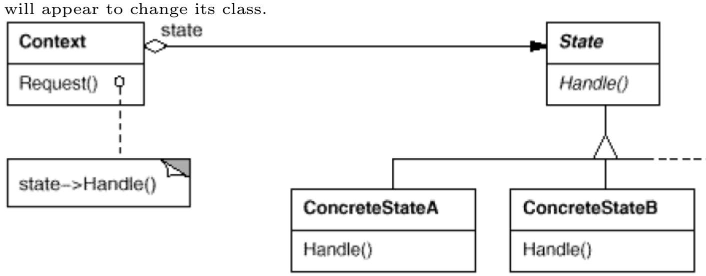
- Object's behaviour depends on its state, and it must change its behaviour at run-time
- Operations have large, multipart conditional statements (Flags) that depend on the state

Intent:

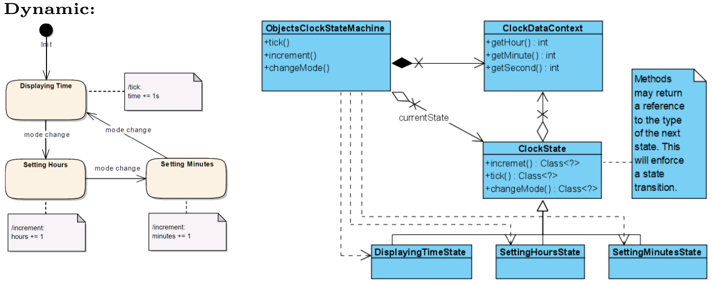
- How can an object act according to its state without multipart conditional statements?

3.4.2 Solution

Allow an object to alter its behaviour when its internal state changes. The object will appear to change its class.



Dynamic:



3.4.3 Summary

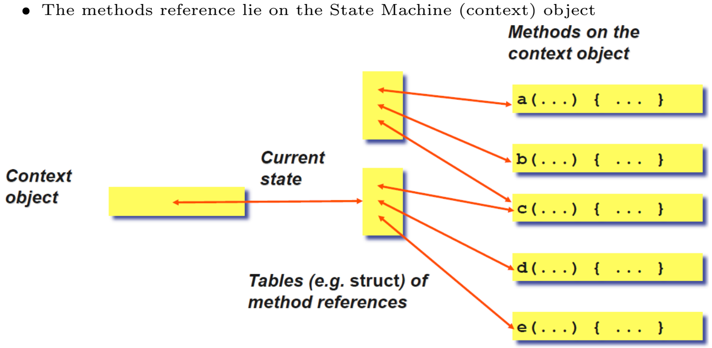
Criticism:

- Complex, but does not adequately cover that complexity
- Overkill in many cases
- Name suggests problem domain rather than the solution

3.5 Methods for State

3.5.1 Solution

- Each state represents a table or record of method references
- The methods reference lie on the State Machine (context) object



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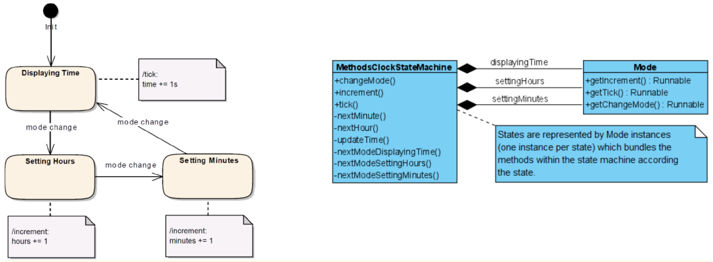


3.5.2 Summary

Benefits

- Allows classes to express different behaviours in ordinary methods themself
- Behaviour coupled to the state machine, not scattered accross small classes
- Each distinct behaviour is assigned its own method

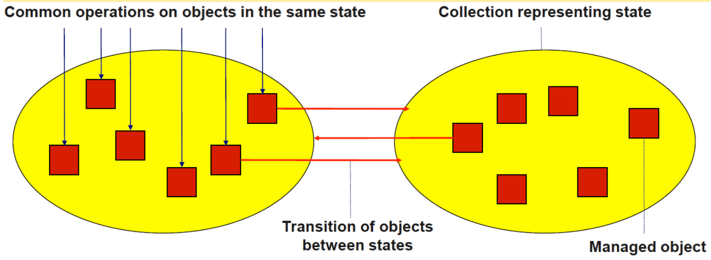
- No object context needs to be passed around, methods can already access the internal stte of the State Machine

Liabilities

- Requires an additional two levels of indirection to resolve a method call
- The state machine may end up far longer than was intended or is manageable

3.6 Collection for State

3.6.1 Solution



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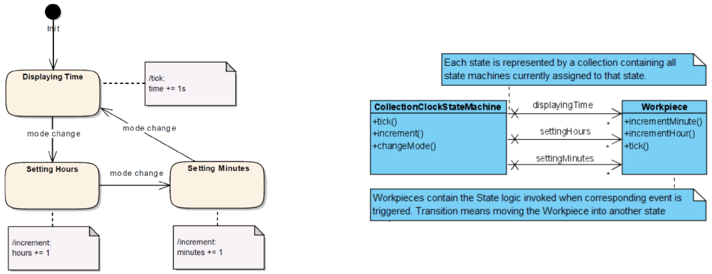


3.6.2 Summary

Benefits:

- No need to create a class per state
- Optimized for multiple objects (state machines) in a state
- Object's collection implicitly determines its state
- Can be compined with other state machine (Objects / Methods)

Liabilities:

- Can lead to a more complex state manager

3.7 Implementation of State Patterns

Objects:

- Results in a lot of classes and structures
- At least one class per state plus state machine

Methods:

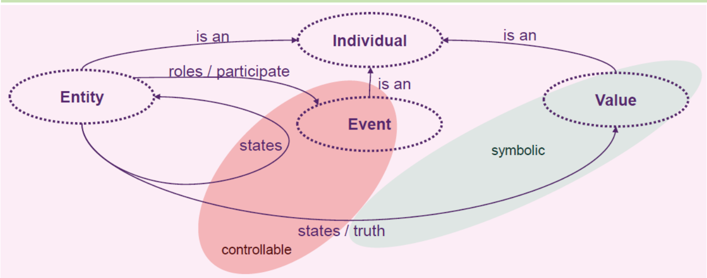
- Propagates a single class with a lot of methods

Collection:

- Allows to manage multiple state machines with the same logic
- Splits logic and transaction management into two classes

4 System Analysis

4.1 Individuals



Events:

- Individual Happening, taking place at some particular point in time
- *E.g. User-Action*

Entities:

- Individual that persists over time and can change its properties and states.
- May initiate events
- May cause spontaneous changes to their own states
- May be passive
- *E.g. Person*

Values:

- Intangible (nicht greifbar) individual that exists outside time and space
- Not subject to change
- *E.g. Körpergrösse*

5 Software Design

5.1 Categories of Objects

Entity

- Express system information
- Typically persistent in nature
- Identity is important to distinguish entity objects

Service

- Represent system activities
- Distinguished by their behaviour rather than their state

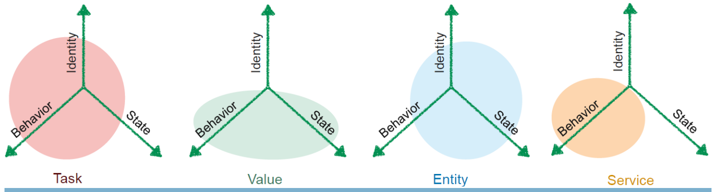
Values

- Interpreted content is the dominant characteristic
- Transient and do not have significant enduring indentity

Task

- Represent system activities
- Have an element of identity and state

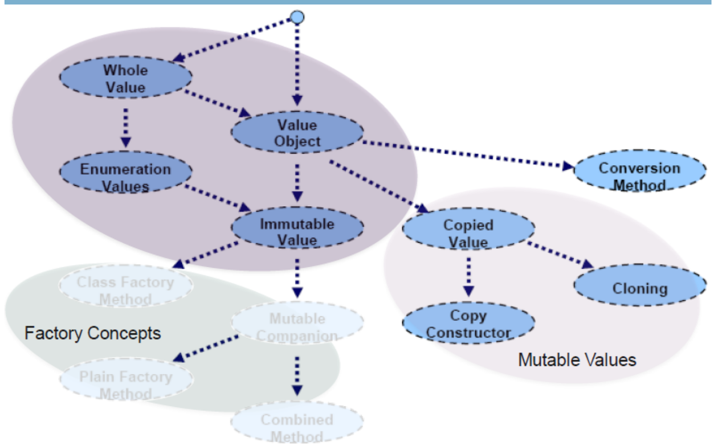
6 Object Aspects



7 Value Objects

- Usually do not appear in UML class diagrams (except attribute type)
- Model fine-grained information
- Contain repetitive common code
- Used to add meaning to primitive value types
- Ensure type safety
- *E.g. IBAN Type Object (10 digits, checksum)*

8 Value patterns



8.1 Whole Value

8.1.1 Problem

- Plain integers and floating-point numbers are not very useful as domain values
- Errors in dimension and intent communication should be addressed at complile time
- How can you represent primitive quantities from your proble domain without loss of meaning?

8.1.2 Solution

Express the type of the quantity as a Value Class.

- Recovers the loss of meaning and checking by providing a **dimension** and **range**
- Wraps simple types or attribute stes
- Disallows inheritance to avoid slicing
- *E.g. Year, Month, Day Classes for Dates*

```
public final class Date {
    public Date(Year year, Month month, Day day) { ... }
}
```

8.2 Value Object / Value Class

8.2.1 Problem

- Comparison, indexing and ordering should not rely on objects identity but its content
- How do you define a class to represent values in your system?

8.2.2 Solution

Override methods in Object whose action should be related to content and not identity and implement serializable.

- Override Object's methods who define equality
- Java
  - *equals(Object other)*
  - *hashCode()*
  - implement *Serializable / toString()* if appropriate
- TypeScript
  - *equals(other: Object)*
  - implement *toString()* if appropriate
- Overriding *toString()* can help using your Value Object

8.3 Conversion Method

8.3.1 Problem

- Values are strongely informational objects without a role for separate identity
- Often Value Objects are somehow related but cannot be used directly without conversion
- How could you use different, related Value Objects together without depending on underlying primitive type?

8.3.2 Solution

Provide type conversion methods responsible for converting Value Objects into related formats.

- Provide a constructor which converts between types *String(char[] value)*
- Or create a conversion instance method that converts to other type *Date.toOtherType()*
- Or create a **Class Factory Method** with conversion characteristics *Date.from(Instant i)*

8.4 Immutable Value

8.4.1 Problem

- A value exists outside time and space and is not subject to change
- Avoid side effect problems when sharing Value Objects
- Sharing values across Threads requires thread safety
- Values are often threaded as key for associative tables
- How can you share Value Objects and guarantee no side effect problems?

8.4.2 Solution

Set the internal state of the Value Class object at construction and allow no modifications.

- Declare all fields private final
- Mark class as final
- No Syncrhonization needed

8.5 Enumeration Values

8.5.1 Problem

- A fixed range of values should be typed *e.g. months*
- Using just int constants doesn't help
- Whole Value is only half the solution; range should be constant
- How can you represent a fixed set of constant values and preserve type safety?

8.5.2 Solution

Treat each constant as Whole Value instance declaring it public.

- Implement a Whole Value and declare the Enumeration Values as *public readonly* fields
- Prevent inadvertently changing the constants
- Pattern is built in (enum)

8.6 Copied Value and Cloning

8.6.1 Problem

- Values should be modifiable without changing the origins internal state
- How can you pass a modifiable Value Object into and out of methods without permitting callers or called methods to affect the original object?

8.6.2 Solution

Implement Cloneable interface to be used whenever a value object needs to be returned or passed as a parameter.

- Clone every Value Object leaked across boundaries (parameters / return values)
- May result in immense object creation overhead (cloning is expensive)
- Imitates *call-by-value* and *return-by-value*

8.7 Copy Constructor

8.7.1 Problem

- Within Value Objects we often know exactly what to copy
- How can objects be copied without the need of implementing a clone method?

8.7.2 Solution

Provide a way to construct an object based on another instance with exactly the same type.

- Declare the class *final* and derive from Object only
- Create a copy constructor, which consumes an instance with same type

```
public final class Date {
    public Date(Date other) {
        // ...
        this.year = new Year(other.year);
    }
}
```

8.8 Class Factory Method / Simple Factory

8.8.1 Problem

- Construction of Value Objects may be expensive
- Different construction logic is required which may result in huge amount of constructors
- How can you simplify and potentially optimize construction of Value Objects in expressions without introducing new intrusive expressions?

8.8.2 Solution

Provide static methods to be used instead of ordinary constructors. The methods return either newly created Value Objects or cached Objects.

- Declare one or more creation method on the class
- Define constructors *private*, they are invoked by Class Factory Method
- The static methods could also contain caching mechanisms

```
public final class Year {
    public static Year of(int value) {
        return new Year(value);
    }
    private Year(int value) { this.value = value; }
}
```

9 Checks