Software Engineering & Projektmanagement VO
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29.05.2019 | **Software Patterns**

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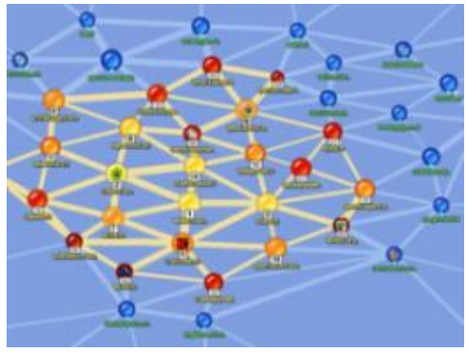
Agenda

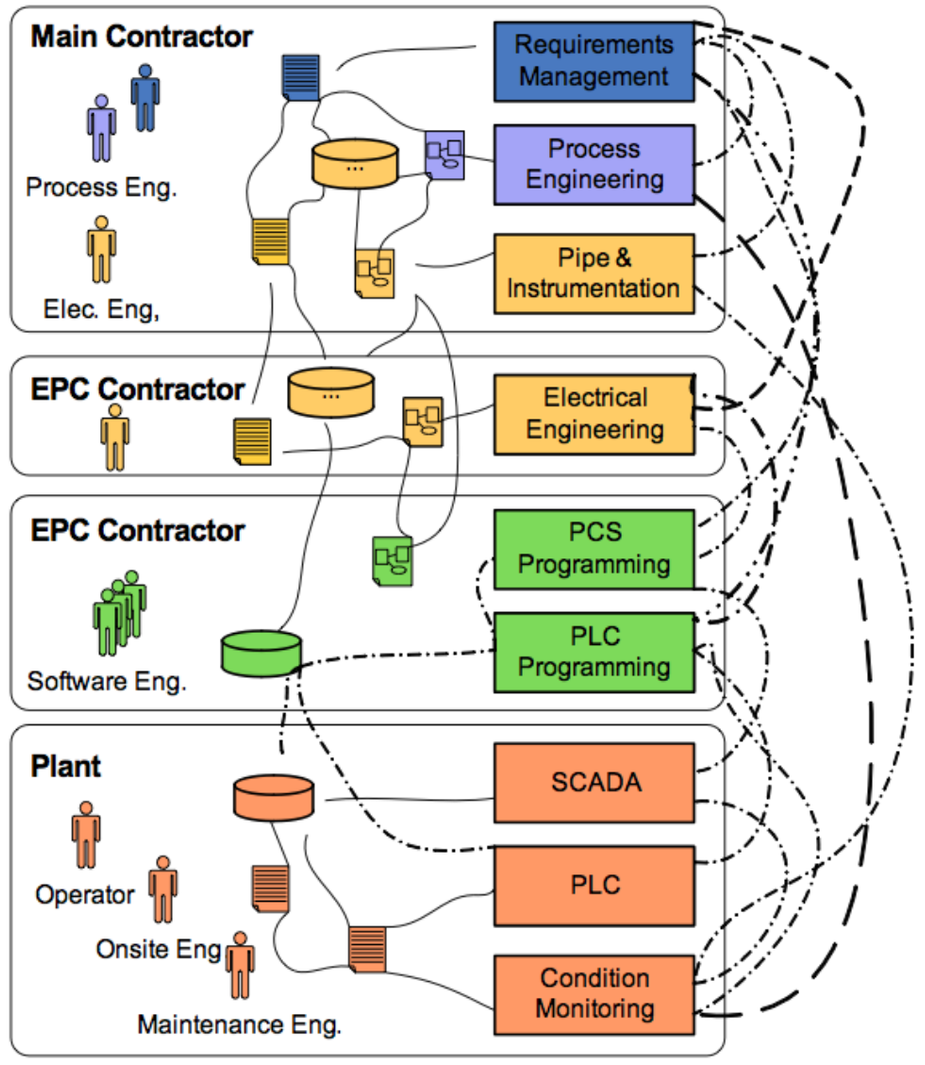
- Industrial Use Case
  - Software Engineering Integration for Flexible Automation Systems
- Complex Systems and Complexity Management
- Motivation for Software Patterns
- Software Pattern Categories
- Practical Examples
  - Engineering Service Bus
- Conclusion



Industrial Scenario

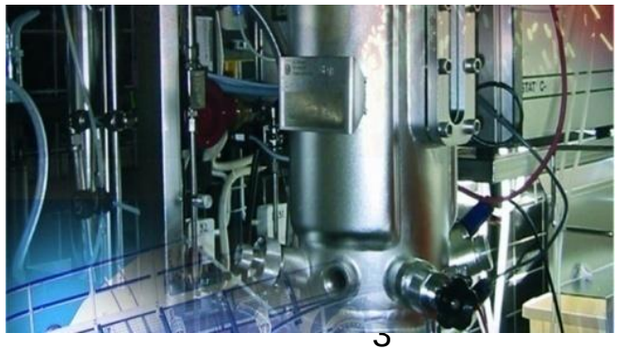
- Large-scale Cyber-Physical (Production) Systems engineering projects
  - e.g. steel-mill, car manufacturing plants, hydro power plants

- Require cooperation of engineers from different disciplines



- Disciplines have specific engineering vocabularies & tools

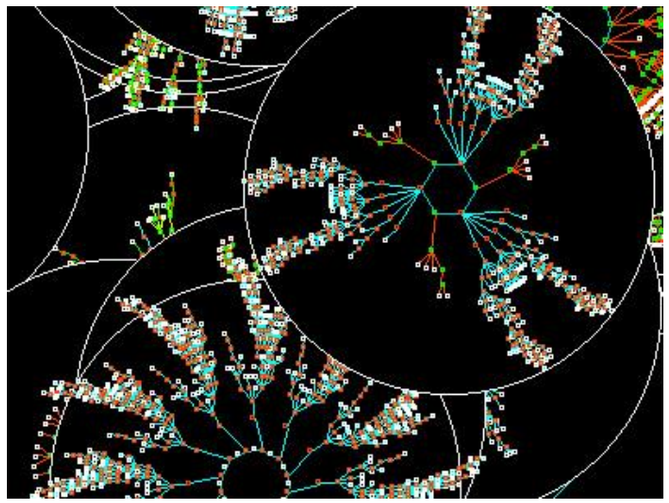
- Manual effort needed for tool data exchange
  - High risks



Complex Systems

Magnitude

- Number of Elements in the system
- Number of possible states of elements
- Difference between number of possible and usable solutions



Diversity

Magnitude of heterogeneity of elements

- Connectivity, structural complexity

  Number of potential connections between elements

- Literature defines systems as complex if
  - … they consists of a large number of interacting components,
  - … simple linear modelling is insufficient for understanding,
  - but requires sophisticated dynamic approaches (e.g., simulations).

Managing Complexity

- Abstraction
  - simplification of a scenario

- Decoupling
  - identify the separation of system components that should not depend on each other

- Decomposition
  - KISS - Keep It Simple, Stupid
  - components that are easier to understand, manage, or maintain
  - problem of reassembling

- Classification
  - system parts with similar properties

Managing Complexity

- Standardization
  - benefit of a structured and non-dynamic environment

- Modeling
  - generating an abstract and simplified view

- Transformation
  - transformation of the given problem to a domain with proven solution approach

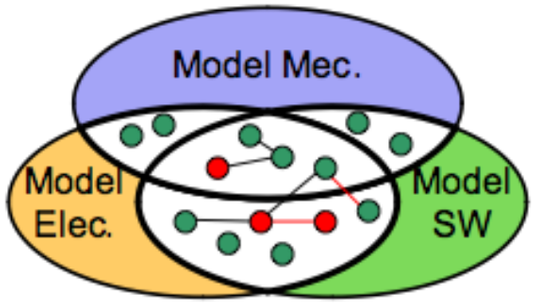
- Experience
  - documented experiences from experienced contributors

Industrial Scenario

- Complexity-drivers
  - **Technical heterogeneity**
    “Engineering Polynesia”
  - **Semantic heterogeneity**
    “Engineering Babylon”
  - **Process heterogeneity**
    “Engineering Chaos”

- Engineering Service Bus
  (https://github.com/openengsb)

- Operating Numbers
  - 184 repositories
  - 5508 Issues
  - 170k LOC
  - 74k LOConf
  - 314 Project Dependencies



Pattern Definitions

- *„…a solution to a problem in a context…“*
- *„A pattern is the abstraction from a concrete form which keeps recurring in specific non-arbitrary contexts”*
- *„Pattern“ has been defined as „an idea that has been useful in one practical context and will probably be useful in others.“*

Elements of a Pattern

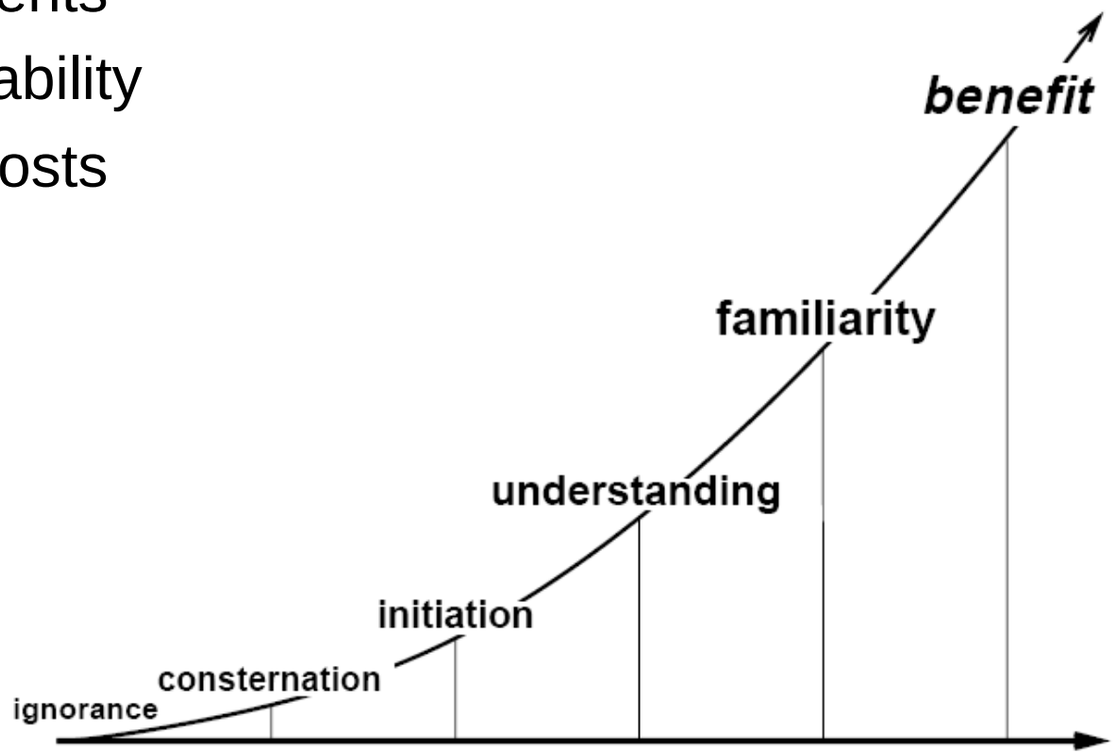
- A meaningful name
  - Aliases, classifications
- Motivation and problem statement
- Context

Elements of a Pattern

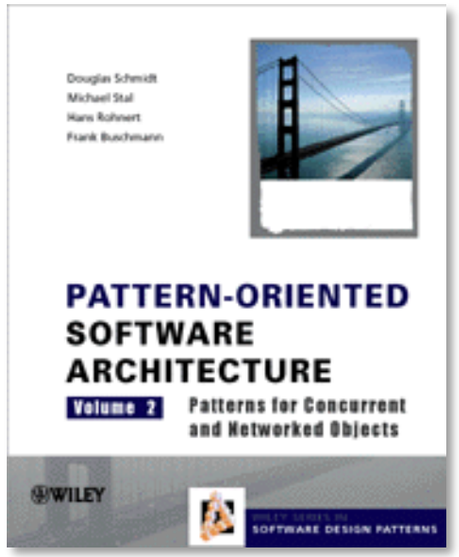
- A meaningful name
  - Aliases, classifications
- Motivation and problem statement
- Context
- Solution
  - Structure
  - Participants
  - Collaboration
  - Consequences
  - Implementation
  - Examples

Advantages for Software Development

- Common vocabulary saves discussions
- Help manage complex systems
  - Patterns explicitly capture expert knowledge and design tradeoffs
    - therefore make this expertise more widely available
  - Combination of patterns
- Facilitates non-functional requirements
  - Reusability, adaptability, extendability
- Minimizes development time and costs
- Improves documentation



Experience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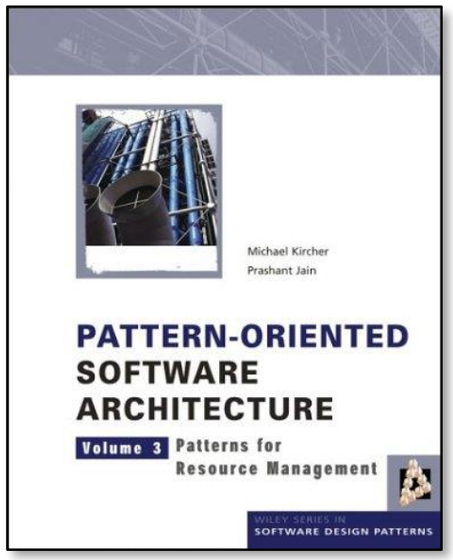
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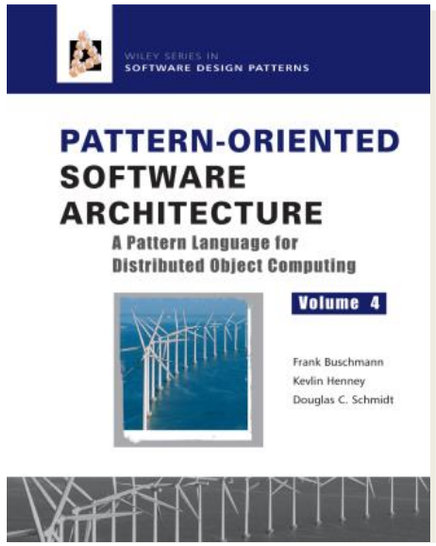
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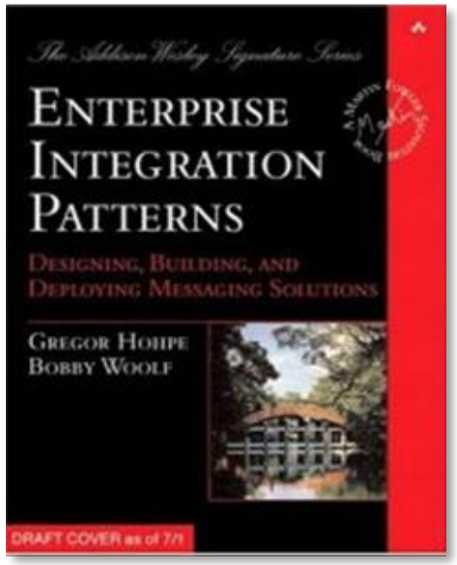
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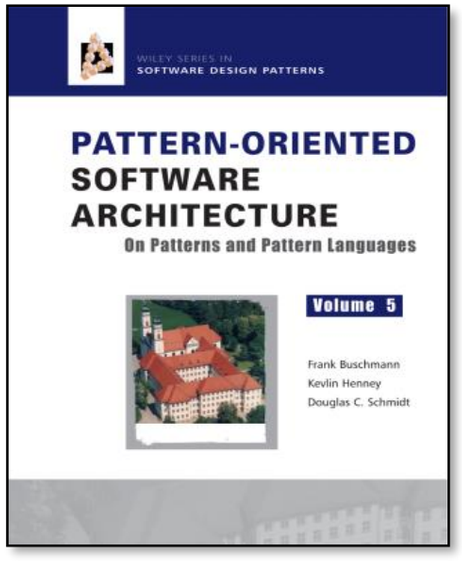
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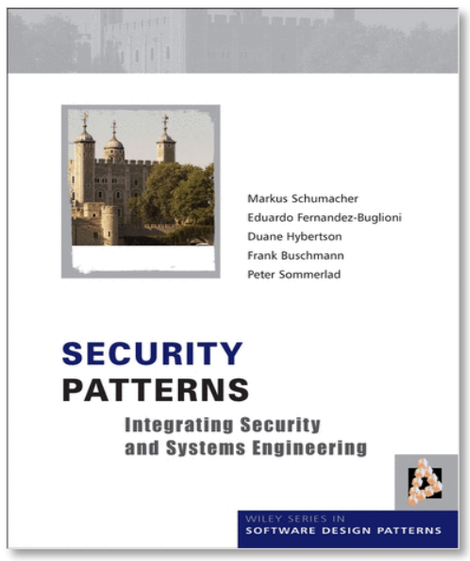
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Drawbacks of Patterns

- Patterns do not lead to direct code reuse
- Patterns are deceptively simple
- Teams may suffer from pattern overload
- Patterns are validated by experience and discussion
  - rather than by automated testing
  - http://clean-code-developer.de/

Classification of Patterns

- Architectural Patterns
  - Structure of software systems
  - Subsystems, dependencies, communication

- Design Patterns
  - Describes the structure and relations at the level of classes
- Idioms
  - Focus on low-level details
  - Programming language specific

- Protopatterns
  - Particular case
  - A new, understandable solution to be used in larger scale

- Antipatterns
  - Commonly used but ineffective techniques

When to use Patterns

- Solutions to problems that recur with variations
  - No need for reuse if the problem only arises in one context
- Solutions that require several steps
  - Patterns can be overkill if solution is simple linear set of instructions
- Solutions where the solver is more interested in the existence of the solution than its complete derivation
  - Patterns leave out too much to be useful to someone who really wants to understand

Most popular Patterns

- The most popular design pattern is the Interface pattern
- The second most popular design pattern is Proxy Pattern
- The third most popular design pattern is "Big Ball of Mud"

http://dilbert.com/strips/comic/1994-06-10/

Types of Patterns

- Fundamental patterns
  - Deal with essential concepts of software architecture

- Creational patterns
  - Deal with initializing and configuring classes and objects

- Structural patterns
  - Deal with decoupling interface and implementation of classes and objects

- Behavioral patterns
  - Deal with dynamic interactions among objects

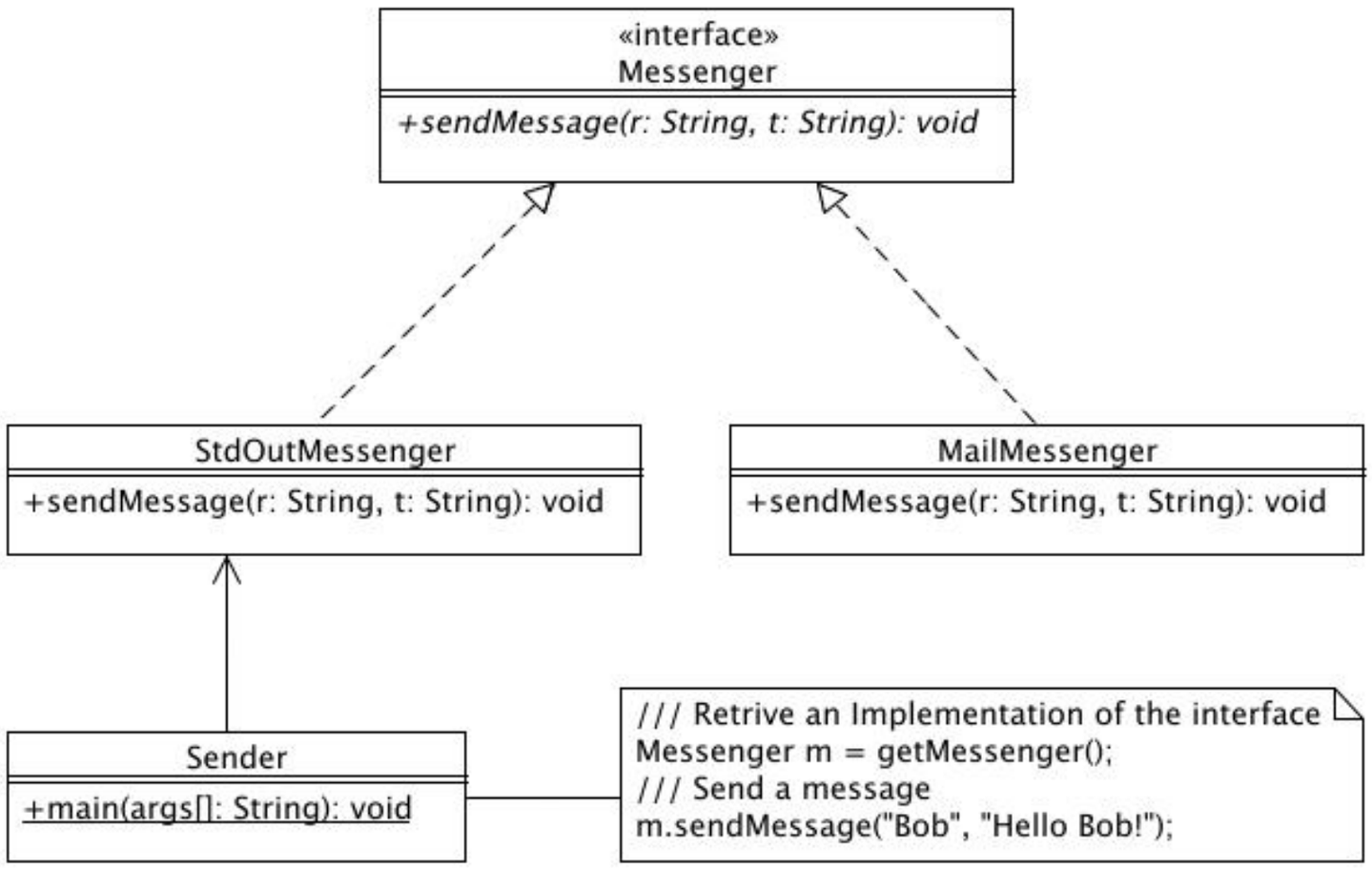
Fundamental Patterns - Overview

- Interface
  - Separation of interface description and implementation
- Delegation
  - Extension of functionality without inheritance
- Immutable
  - Provides unchangeable object after initialization
- Marker / Annotation
  - Enhances objects with metadata

Fundamental Pattern - Interface

Issue: Separate Interface description and concrete implementation

- defines the signature operations of an entity
- should be stable - in comparison to implementation
- implementations can be added / changed easily



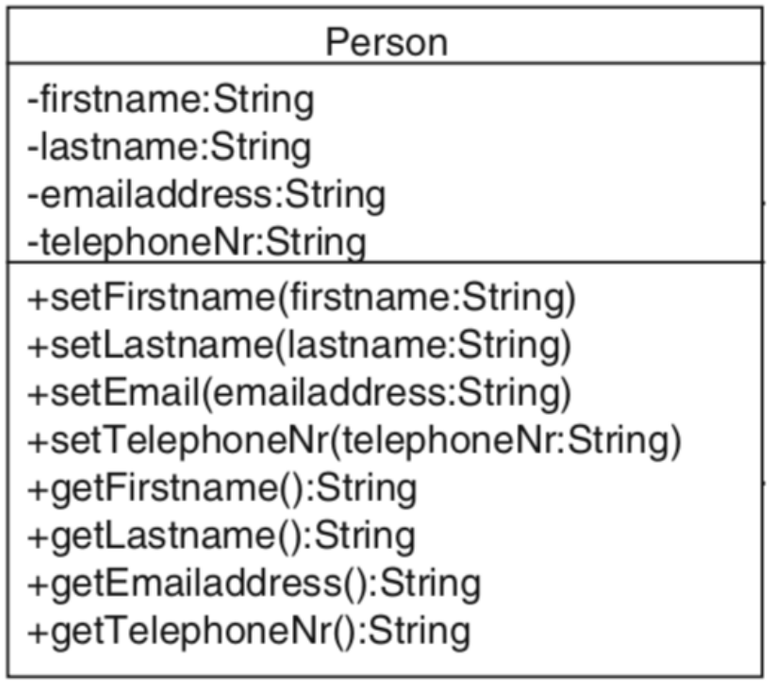
Fundamental Pattern - Interface

Code Example

```java
package at.sqi.patterns;

interface Messenger { void sendMessage(String receiver, String message); }

public class TwitterMessenger implements Messenger {
    void sendMessage(String receiver, String message) {
        setReceiver(receiver);
        setMessage(message);
        commit();
    }
}

public class SystemOutMessenger implements Messenger {
    void sendMessage(String receiver, String message) {
        System.out.println("Message to " + receiver);
        System.out.println(message);
    }
}

```

Fundamental Pattern - Delegation

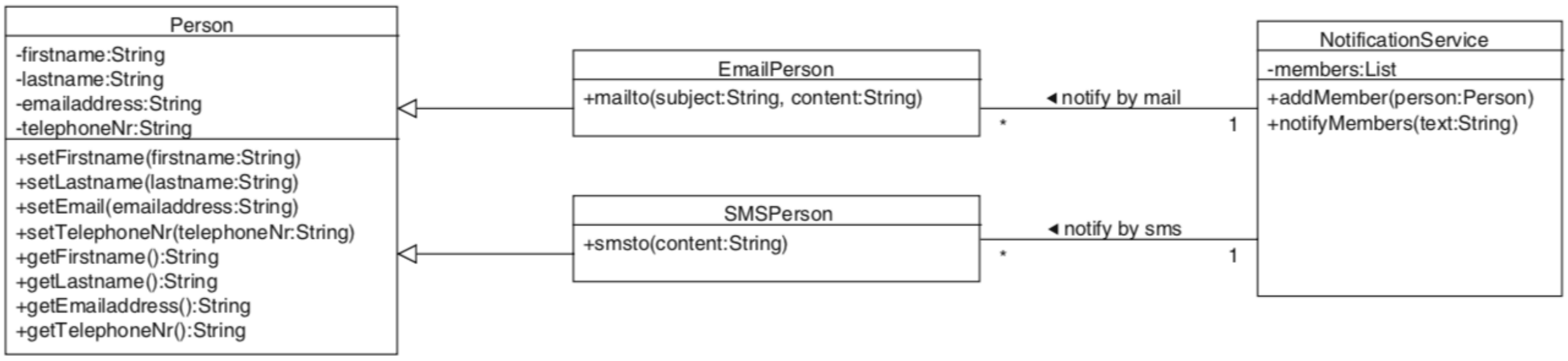
Issue: Class needs additional functionality



Fundamental Pattern - Delegation

Issue: Class needs additional functionality

Inheritance

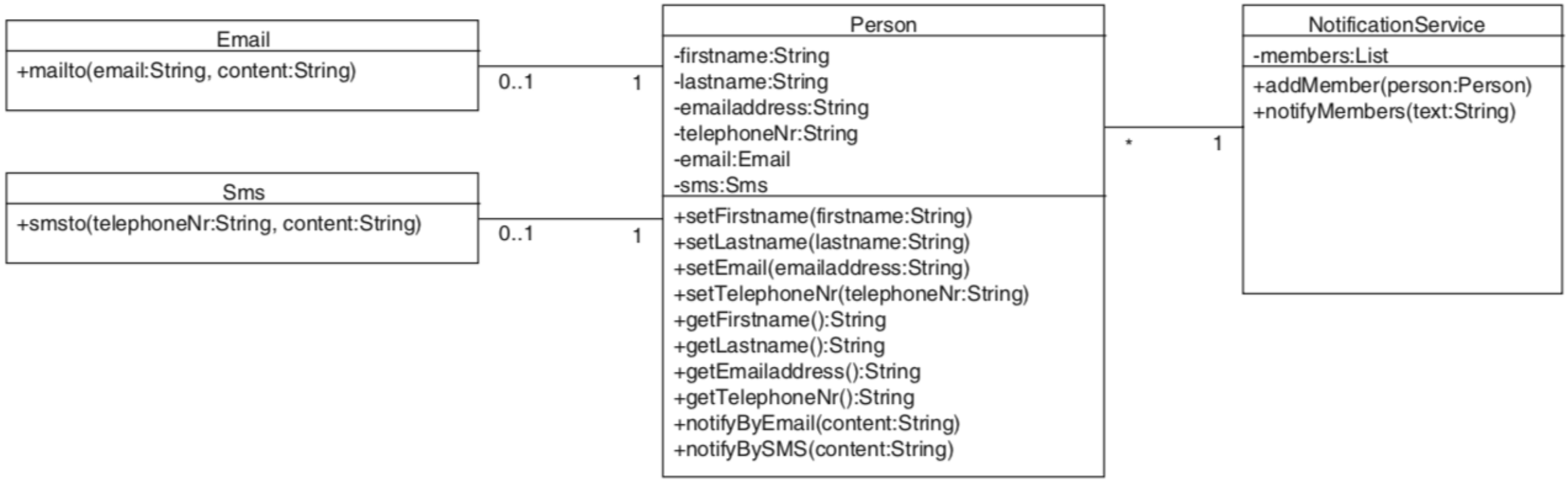


Fundamental Pattern - Delegation

Issue: Class needs additional functionality

Delegation

Outsource functionality into third class and use its instance via delegation



Fundamental Pattern - Delegation

Code Example

```
    }

    @Override
    public Object handleInvoke(Object proxy, Method method, Object[] args) throws IllegalAccessException,
        InvocationTargetException {
        checkMethod(method);
        forwardEvent((Event) args[0]);
        return null;
    }

    private void forwardEvent(Event event) throws InvocationTargetException {
        LOGGER.info("Forwarding event to workflow service");
        try {
            workflowService.processEvent(event);
        } catch (WorkflowException e) {
            throw new InvocationTargetException(e);
        }
    }
```

Fundamental Pattern - Immutable

Issue: Object instance should be immutable

- Several threads accessing same object
- Configuration object properties

Immutable Object

- Initialize variables in constructor
- Provide readable only access via Getter-Methods

Fundamental Pattern - Immutable

Code Example

```java
package at.sqi.patterns;

import java.util.Date;

public class Person {
    private final Date birthday;

    public Person(Date birthday) { this.birthday = birthday; }

    public Date getBirthday() { return  this.birthday; }
}

```

Creational Patterns - Overview

- Singleton
  - Provision of a single instance only
- Factory
  - Method in a derived class creates associates
- Abstract Factory
  - Factory for building related objects without specifying their concrete classes
- Builder
  - Factory for building complex objects in different variants
- Prototype
  - Factory for cloning new instances from a prototypical instance

Creational Pattern - Singleton

Issue: Only one object instance should exist

- Database access
- Id generator
- Logger
- Communication with hardware

Creational Pattern - Singleton

Issue: Only one object instance should exist

Singelton

```
1   package at.sqi.patterns;
2
3   import org.slf4j.Logger;
4   import org.slf4j.LoggerFactory;
5
6   public class LoggerProviderThread {
7       private static Logger LOG;
8
9       public Logger getLogger() {
10          if (this.LOG == null) {
11              this.LOG = LoggerFactory.getLogger(LoggerProviderThread.class);
12          }
13          return this.LOG;
14      }
15  }
16
```

Threadsafe??

Creational Pattern - Singleton

Code Example

```
2
3   import org.slf4j.Logger;
4   import org.slf4j.LoggerFactory;
5
6   public class Person {
7       private final Logger LOG = LoggerFactory.getLogger(Person.class);
8
9       Logger getLogger() {
10          return LOG;
11      }
12  }
13
```

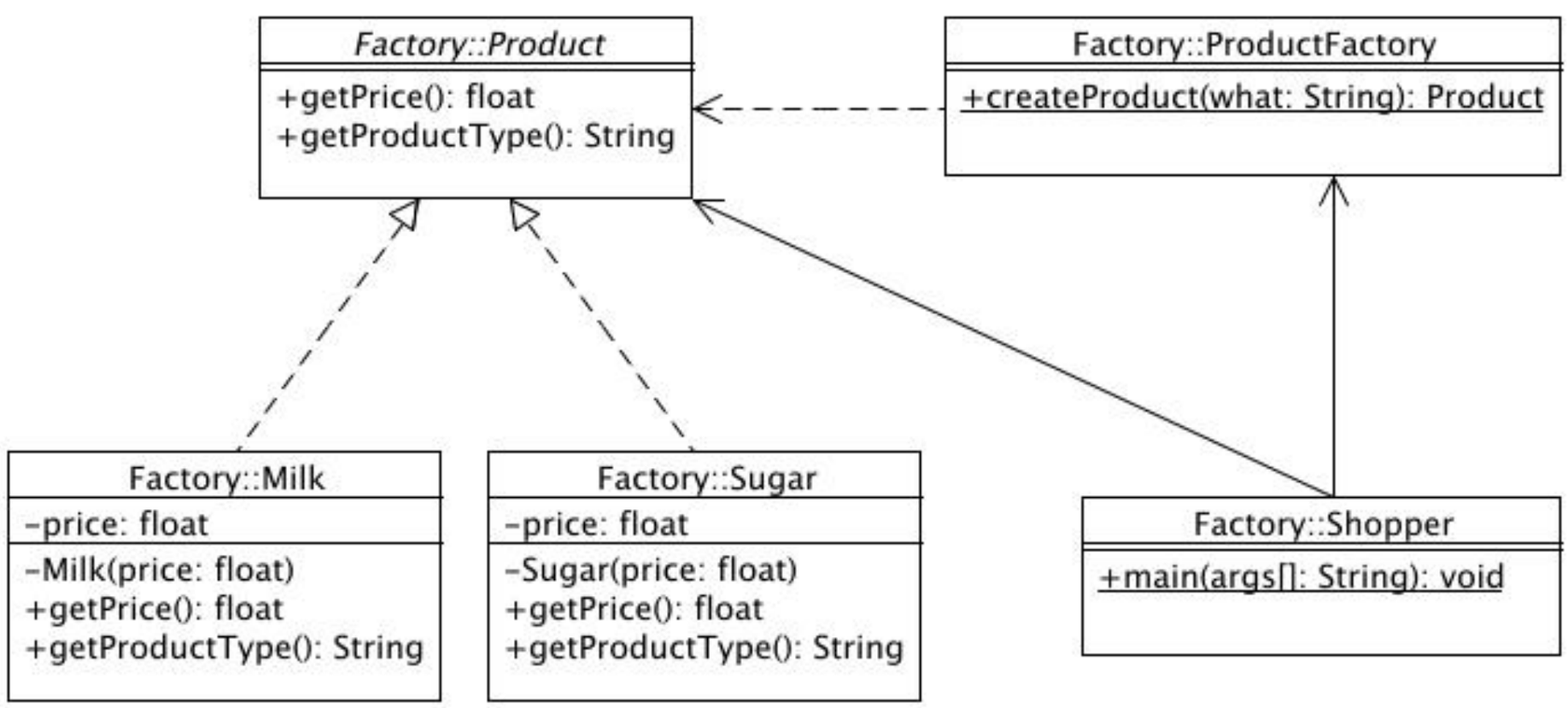
In this case *LOG* is the same object even without static due to the Singleton Pattern of the *LoggerFactory* considering the *Person.class* parameter

Creational Pattern - Factory

Issue: Object creation depends on complex requirements

- Initialization of additional sub-instances required
- Complex configuration process steps

Helps decoupling as only interface is known!



Creational Pattern - Factory

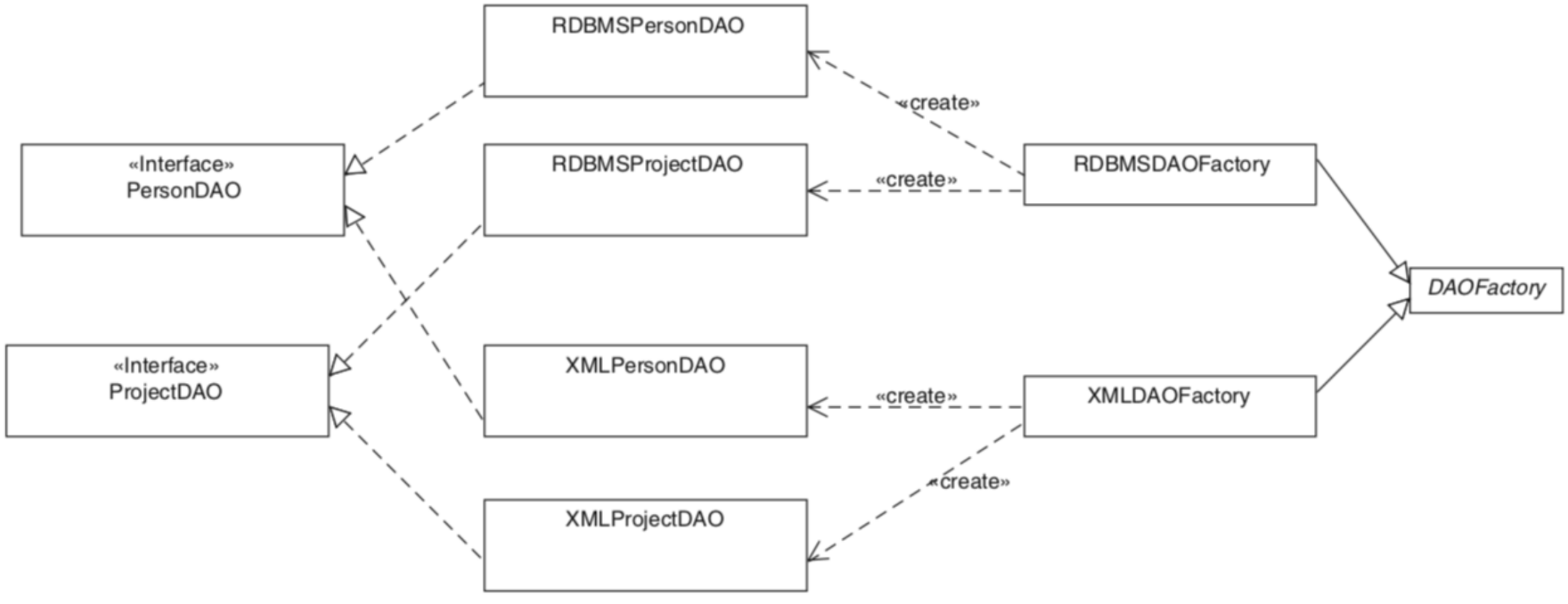
Code Example

```
3   interface Product { float getPrice(); }
4
5   public class Milk implements Product {
6       final float price;
7
8       public Milk(final float price) { this.price = price; }
9
10      public float getPrice() { return price; }
11  }
12
13  public class Sugar implements Product {
14      final float price;
15
16      public Sugar(final float price) { this.price = price; }
17
18      public float getPrice() { return price; }
19  }
20
21  public class ProductFactory {
22      public static Product createProduct(String what) {
23          // When sugar is requested, we return sugar:
24          if (what.equals("Sugar")) { return new Sugar( price: 1.49F); }
25          // When milk is needed, we return milk:
26          else if (what.equals("Milk")) { return new Milk( price: 0.99F); }
27          // Otherwise return at least sugar
28          else { return new Sugar( price: 1.49F); }
29      }
30  }
31
```

Creational Pattern – Abstract Factory

Issue: Achieving higher abstraction by grouping individual factories with a common theme

- Abstract Factory
  - a group of individual factories that have a common theme
- Two hierarchies
  - various abstractions client is interested in
  - abstract AbstractFactory class provides interface
    - for each class that is responsible for creating the members of a particular family
- Client only knows abstract interface
  - Family may grow independently of the client



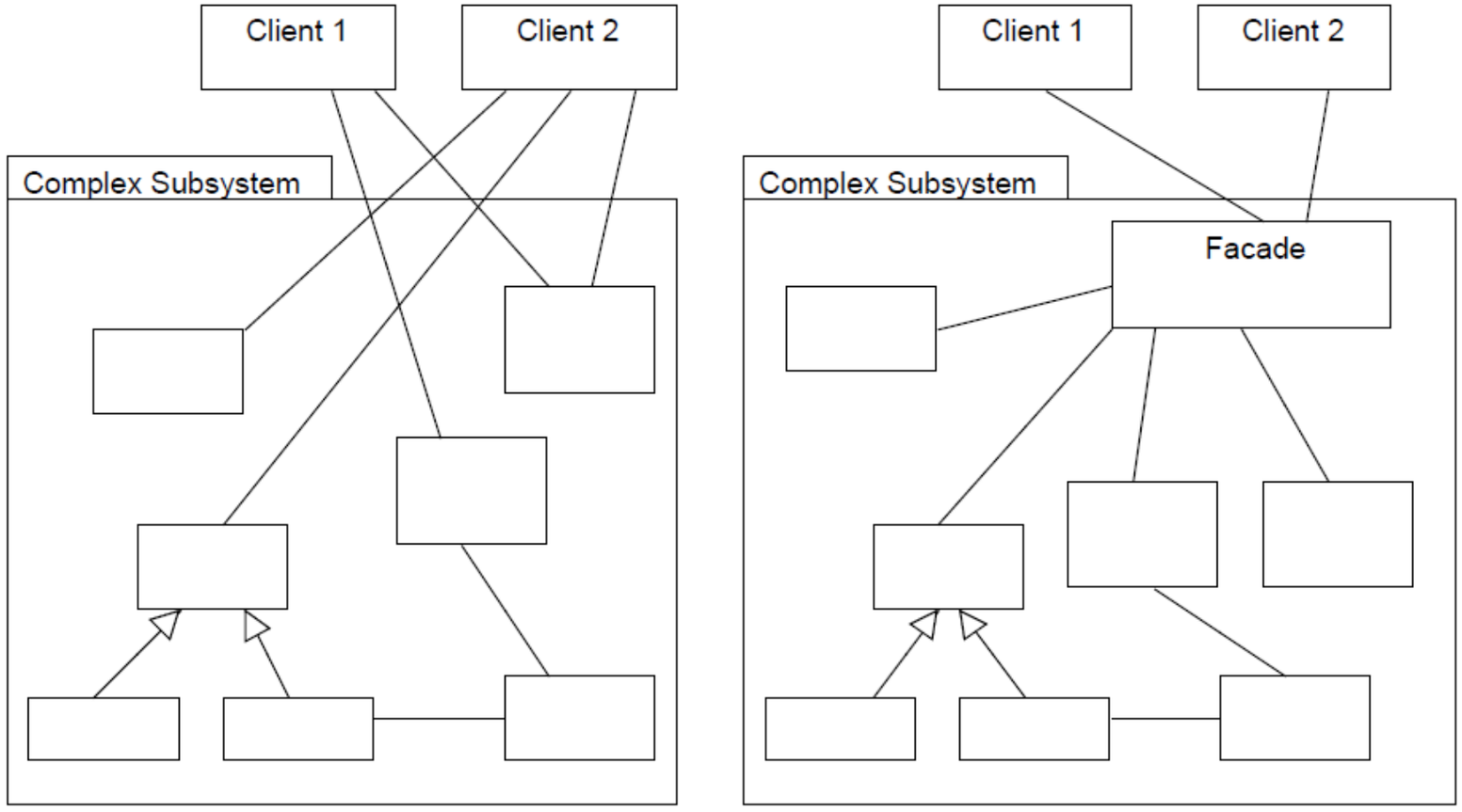
Structural Patterns - Overview

- Facade
  - Facade simplifies the interface for a subsystem
- Adapter
  - Translator adapts a server interface for a client
- Proxy
  - One object approximates another
- Bridge
  - Abstraction for binding one of many implementations
- Composite
  - Treats individual objects and compositions uniformly
- Flyweight
  - Many fine-grained objects shared efficiently

Structural Pattern - Facet

Issue: Need simplified access to a complex subsystem

- Provides a simplified, higher-level interface of a subsystem
  - easier to use, understand, and test subsystem
  - balance between simple but restricted and rich but complex
- May help creating a layered architecture



Structural Pattern - Facet

Code Example

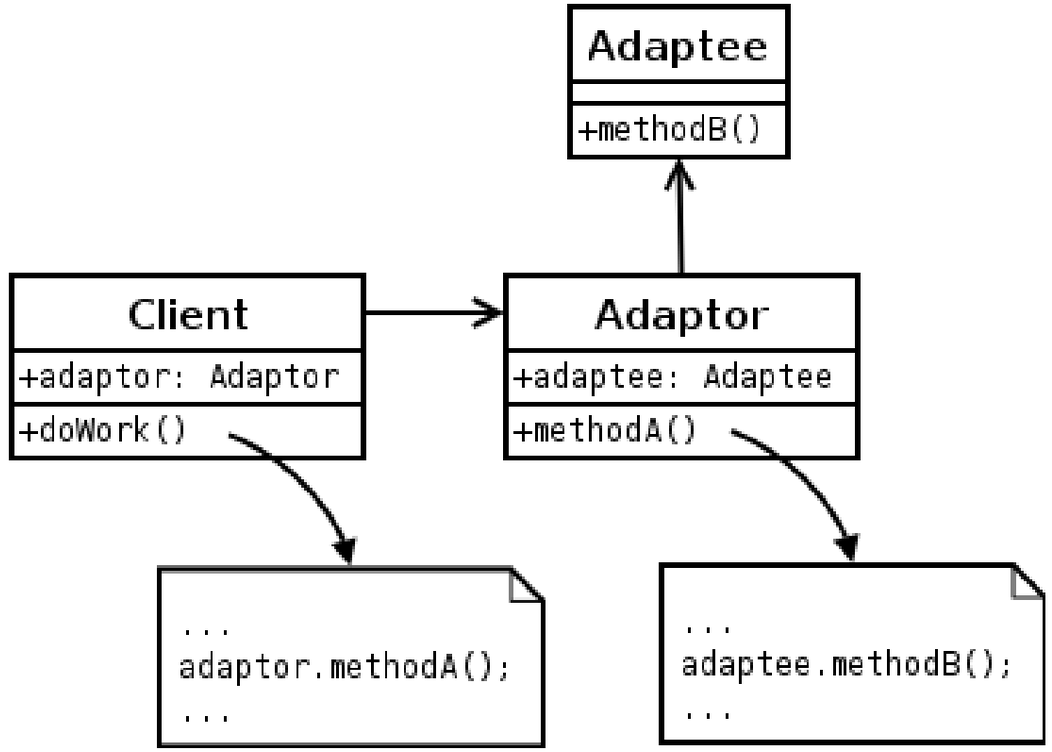
```java
package at.sqi.patterns;

public class SimpleMail {
    public static int sendMail(String address, String subject, String body) {
        int status = 0;
        // Complex mail sending operation
        return status;
    }
}

```

Structural Pattern - Adapter

Issue: Need to integrate incompatible external functionality

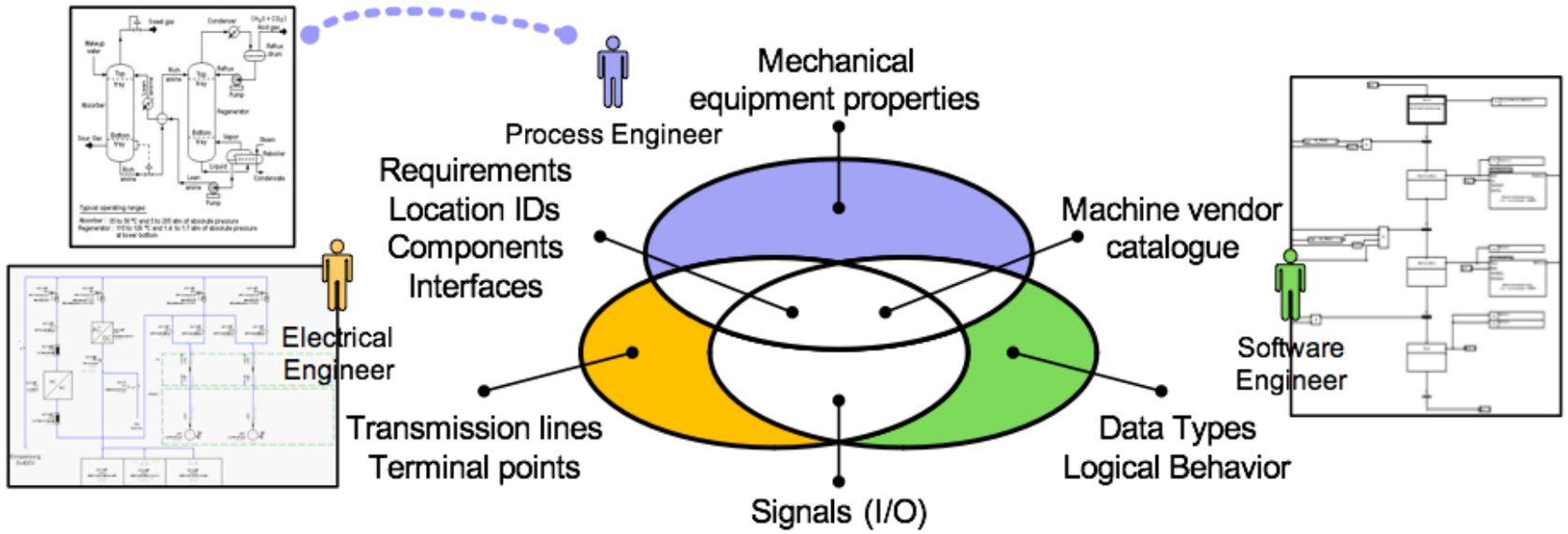
- wrapper pattern or simply a wrapper
- provides access to external functionality
  - e.g., access to external libraries, (proprietary) systems
  - typically no direct access because of incompatible interfaces

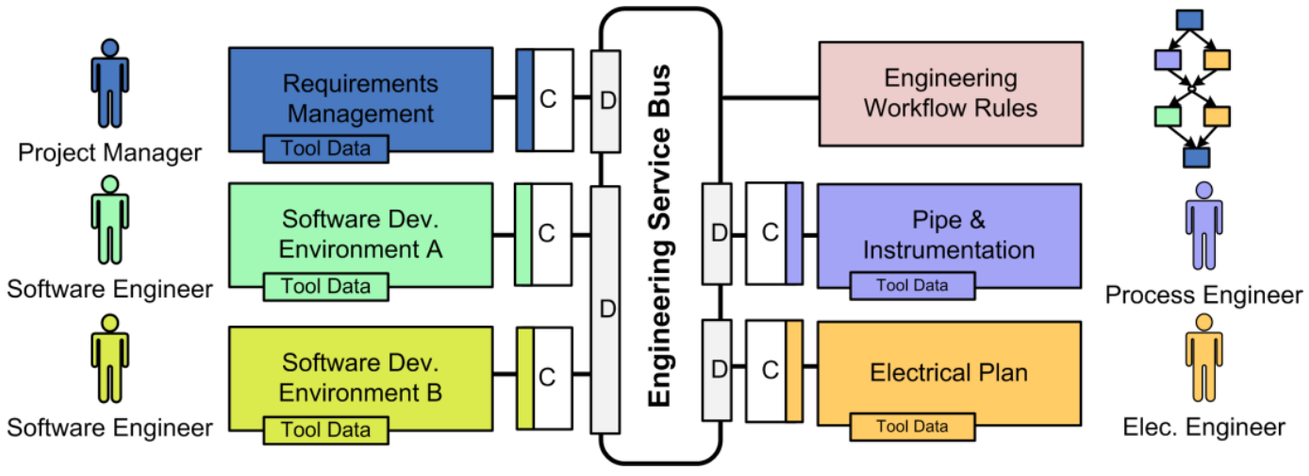
- translates an external interface into a compatible interface
  - Perform data transformations into appropriate forms



Structural Pattern - Adapter

OESB Example



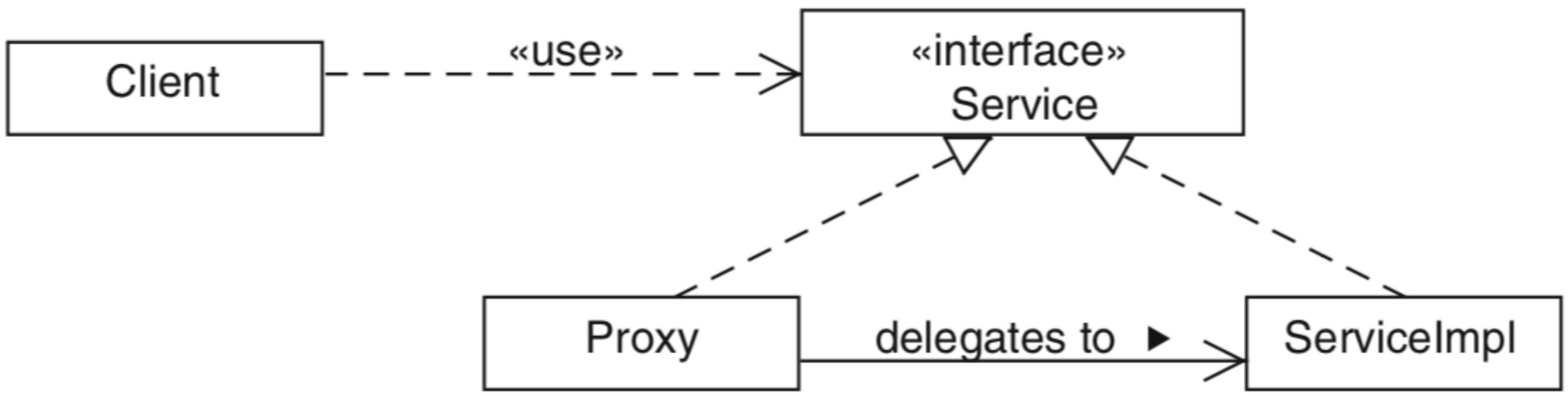


Structural Pattern - Proxy

Issue: Need to integrate further actions before intended method call

- Extends concept of the delegation pattern
- Enriches interface functionality
  - Implements interface and acts as a representative of the „original“ implementation
- Cascading Proxies

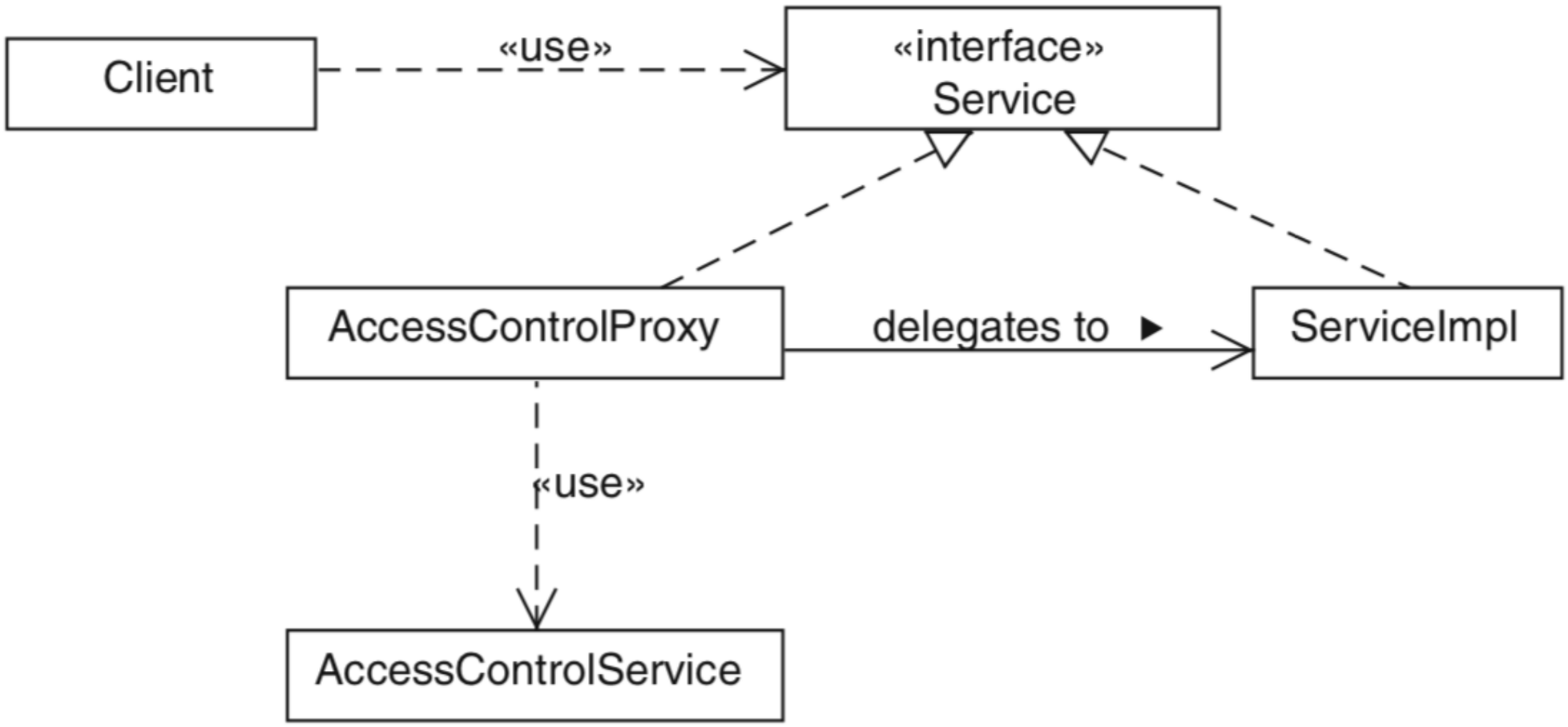
- Use cases
  - security
  - logging
  - caching



Structural Pattern - Proxy

Issue: Need to integrate further actions before intended method call

Use case: **Access control**



Remote Connectors

Code Example

```
@Override
public Object doInvoke(Object proxy, Method method, Object[] args) throws Throwable {
    List<String> paramTypeNames = getParameterTypesAsStrings(method);

    MethodCall methodCall = new MethodCall(method.getName(), args, metadata, paramTypeNames);
    MethodResult callResult = portService.sendMethodCallWithResult(portId, destination, methodCall);

    switch (callResult.getType()) {
        case Object:
            return callResult.getArg();
        case Void:
            return null;
        case Exception:
            throw new RuntimeException(callResult.getArg().toString());
        default:
            throw new IllegalStateException("Return Type has to be either Void, Object or Exception");
    }
}
```

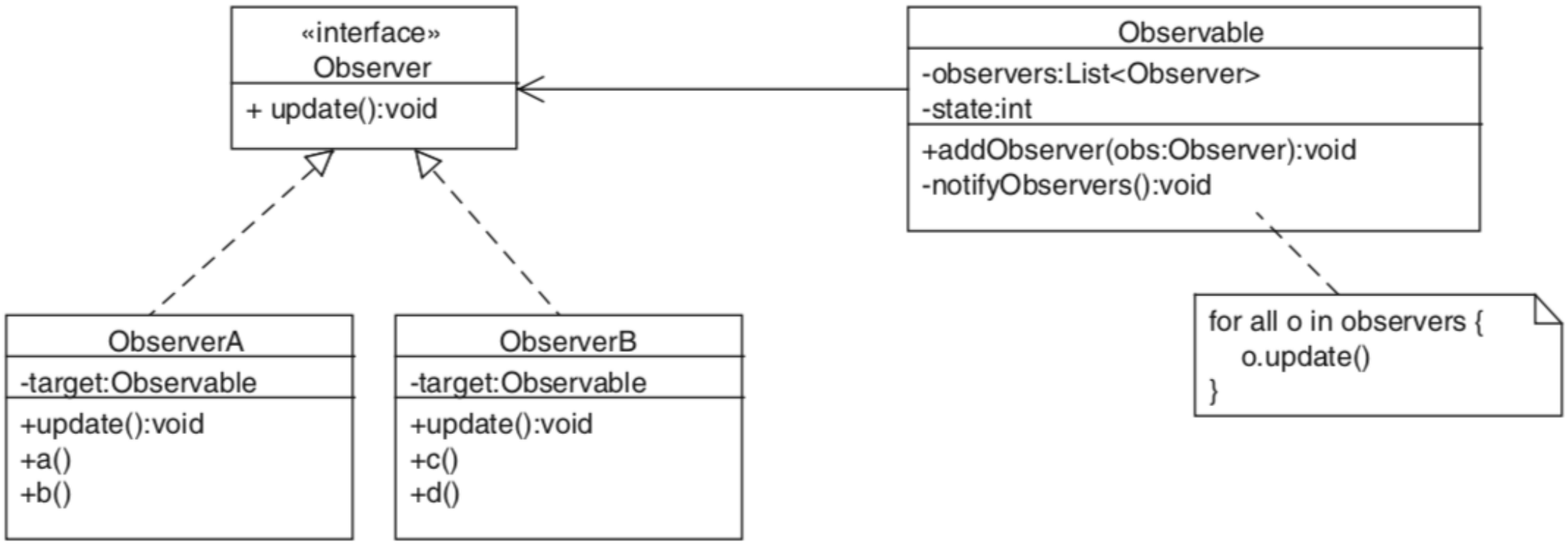
Behavioral Patterns - Overview

- Observer
  - Dependents update automatically when a subject changes
- Decorator
  - Decorator extends an object transparently
- State
  - Object whose behavior depends on its state
- Strategy
  - Vary algorithms independently
- Chain of Responsibility
  - Request delegated to the responsible service provider
- Iterator
  - Aggregate elements are accessed sequentially
- Command
  - Object represents all the information needed to call a method at a later time
- Mediator
  - Mediator coordinates interactions between its associates
- Memento
  - Snapshot captures and restores object states

Behavioral Pattern - Observer

Issue: Need to react to object state changes

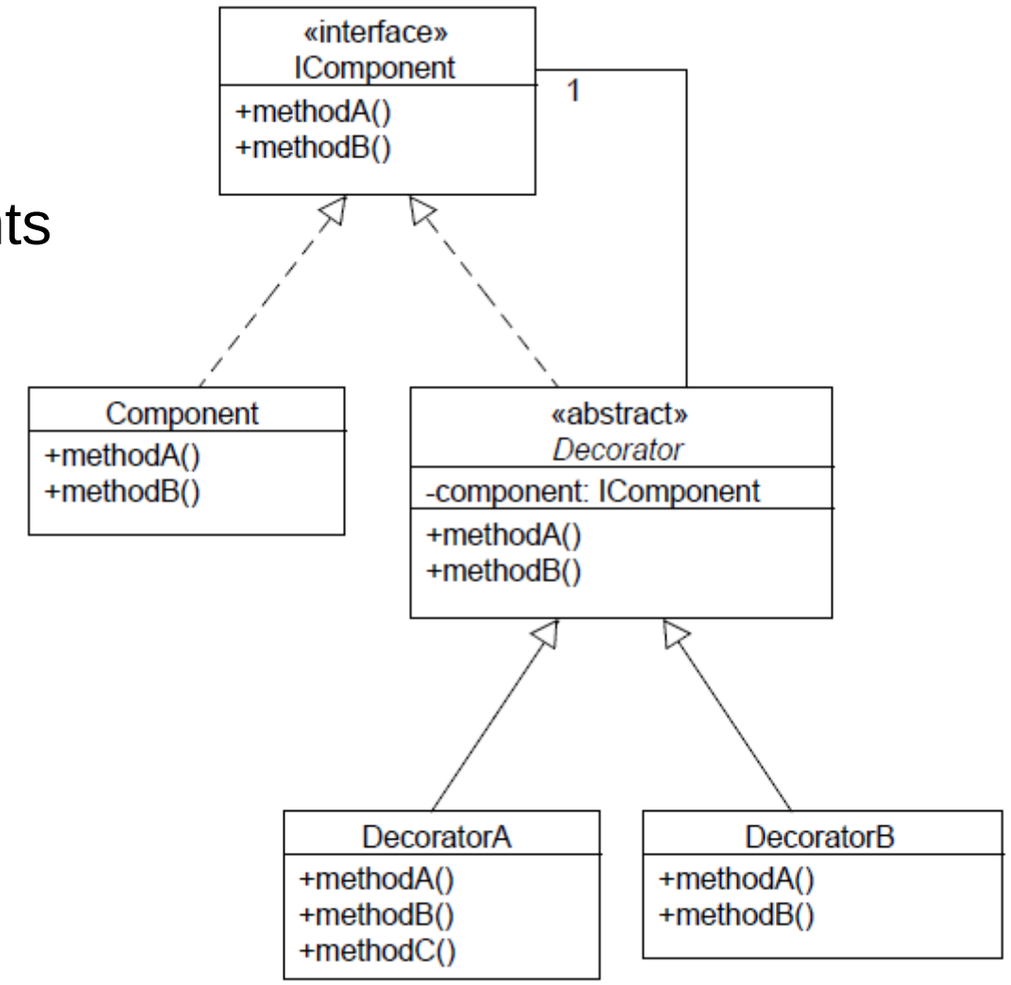
- in case of changes of the instance‘s state execute specific action(s)
  - e.g., notification of instances interested in change
  - one-to-many dependency



Behavioral Pattern - Decorator

Issue: Need to extend object functionality during runtime

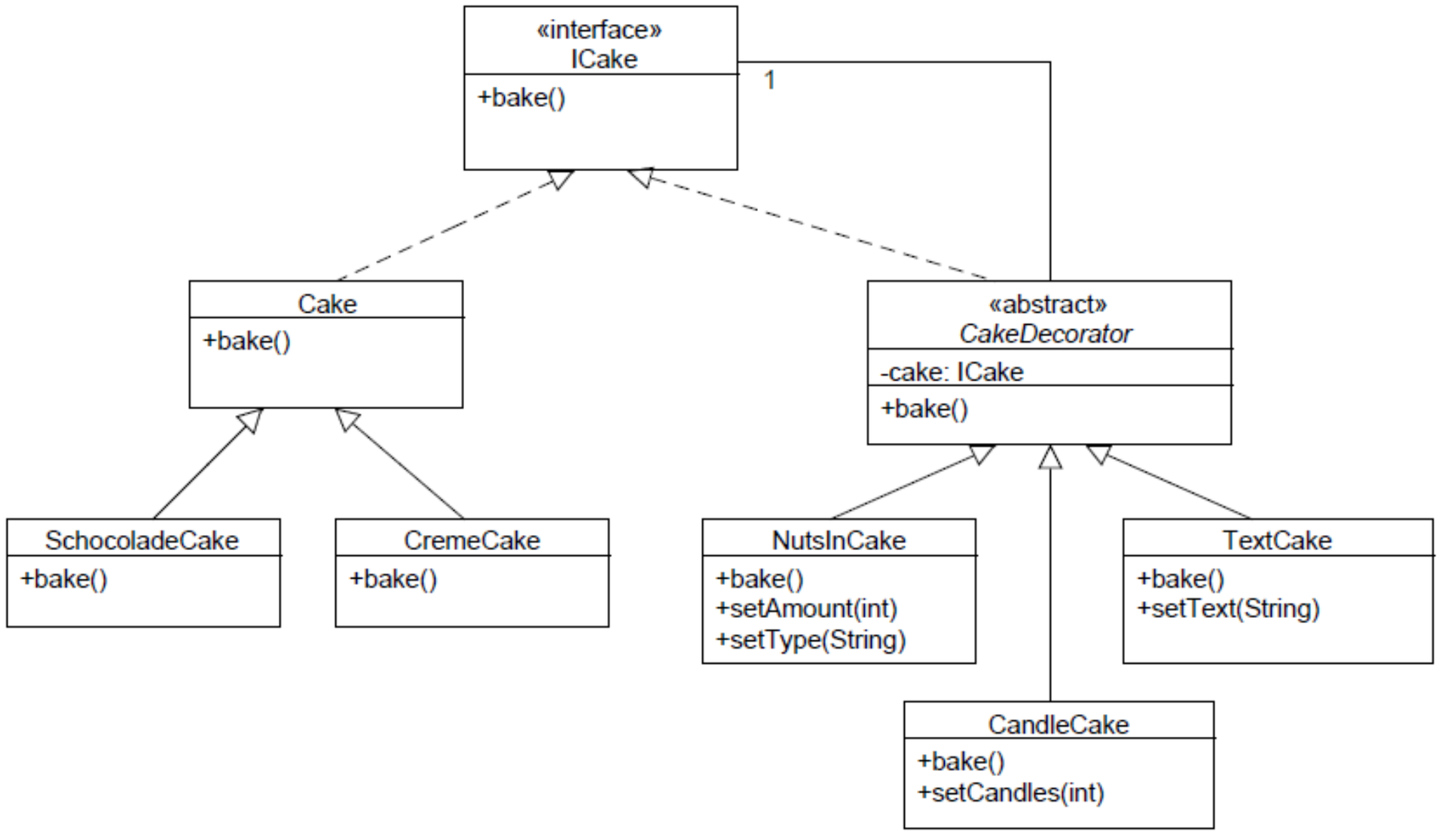
- Dynamically add new functionality to an existing object
  - Some basic work still has to be done at design time
- Elements
  - Interface Component
  - Implemented by concrete components
  - Abstract decorator class
    - Implements interface
    - and keeps reference to interface to forward functionality
  - Concrete decorator implementations
- Drawback
  - Testing
  - proxy



Behavioral Pattern - Decorator

Issue: Need to extend object functionality during runtime

Example: **Cake**

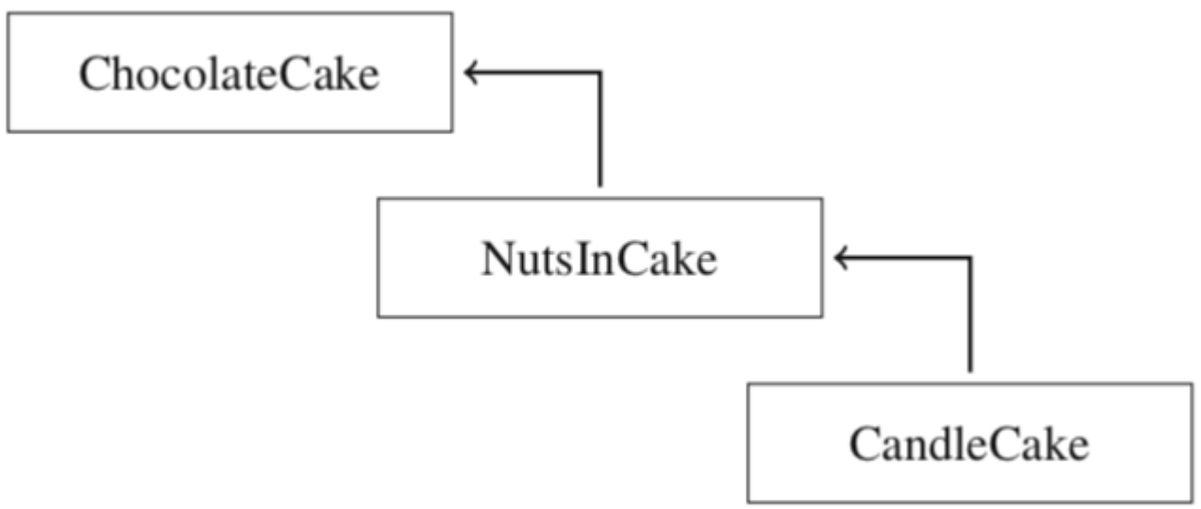


Behavioral Pattern - Decorator

Issue: Need to extend object functionality during runtime

Example: **Cake**

```
Cake cake = new ChocolateCake();

NutsInCake nic = new NutsInCake(cake);
nic.setAmount(15);
nic.setType("hazelnut");
CandleCake cc = new CandleCake (nic);
cc.setCandles(13);
cake = (Cake)cc;

cake.bake();
```



Behavioral Pattern - Decorator

Issue: Need to extend object functionality during runtime

Example: **GUI toolkit**

```
VisualComponent vc = new ScrollBar(
  new Border( new TextEditor() ));
vc.draw();
```

Behavioral Pattern - Decorator

Issue: Need to extend object functionality during runtime

Example: **Stream**

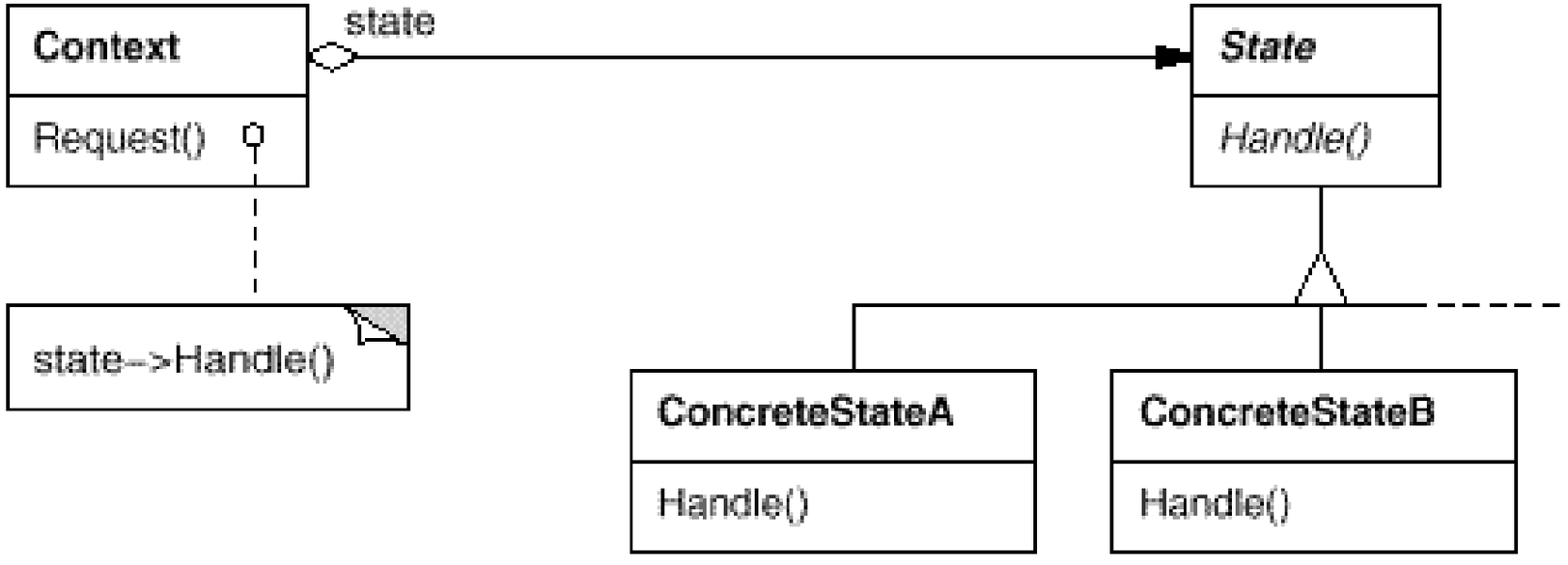
```
Stream s = new FileStream(filename);
```

```
Stream s = new CompressingStream(
               new BufferedStream(
                  new FileStream(filename)
               )
           );
```

Behavioral Pattern - State

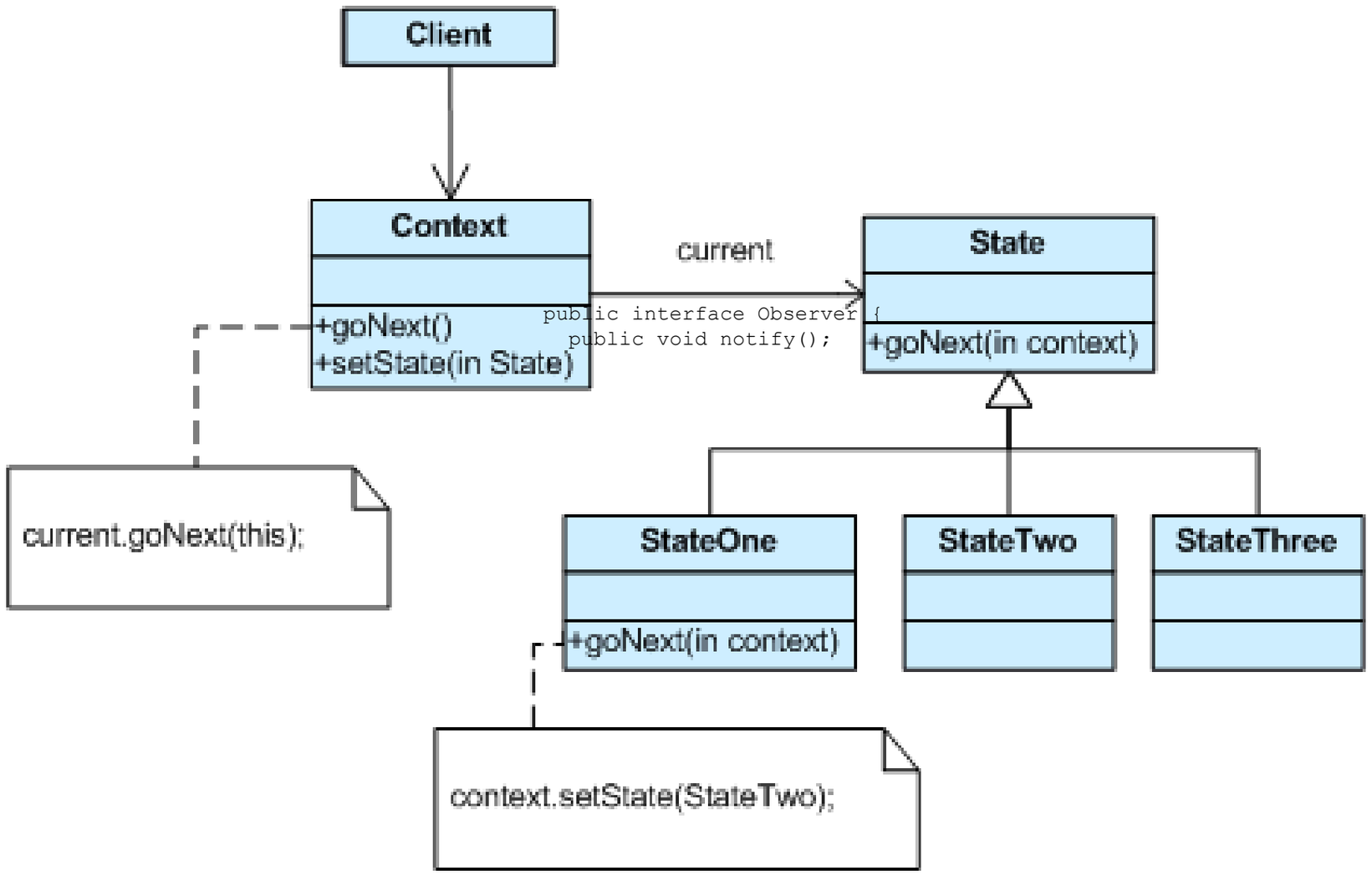
Issue: Need to change object behavior based on current state

- Allow an object to update its behavior when its internal state changes
  - Makes state transitions explicit
  - May result in lots of subclasses



Behavioral Pattern - State

Issue: Need to change object behavior based on current state

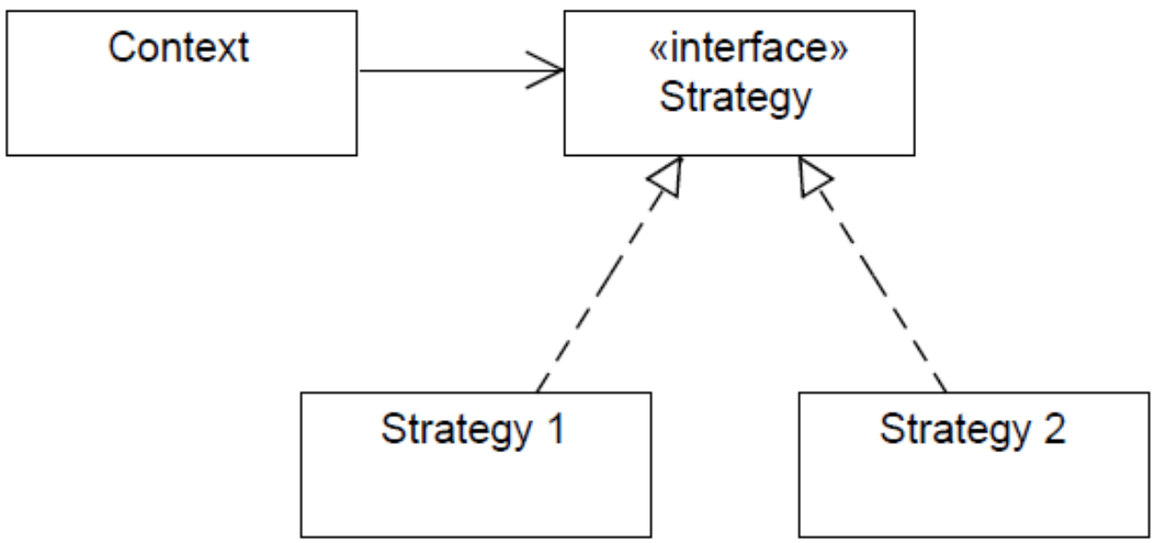


http://sourcemaking.com/design_patterns/state

Behavioral Pattern - Strategy

Issue: Need to extend strategies at runtime

- Dynamically add new algorithms
  - context choose algorithm to use

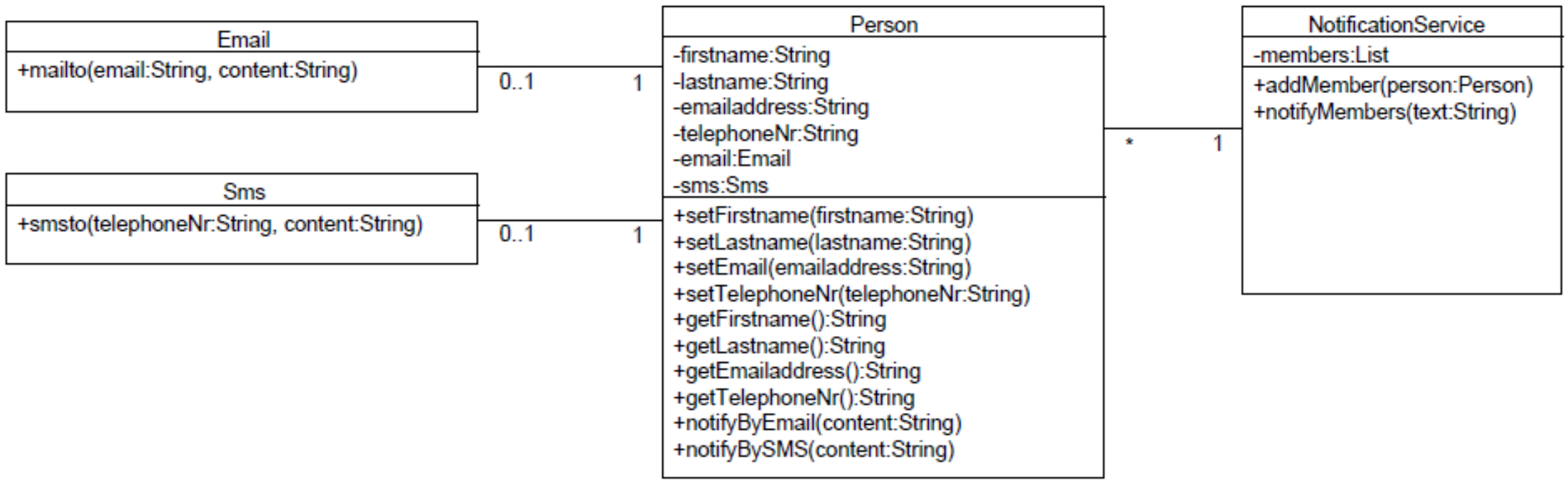


Behavioral Pattern - Strategy

Issue: Need to extend strategies at runtime

Example: **Notification strategy**

- Currently close binding between person and email/sms
  - no use of additional communication technique without changing code
  - Notification service decides technique of communication

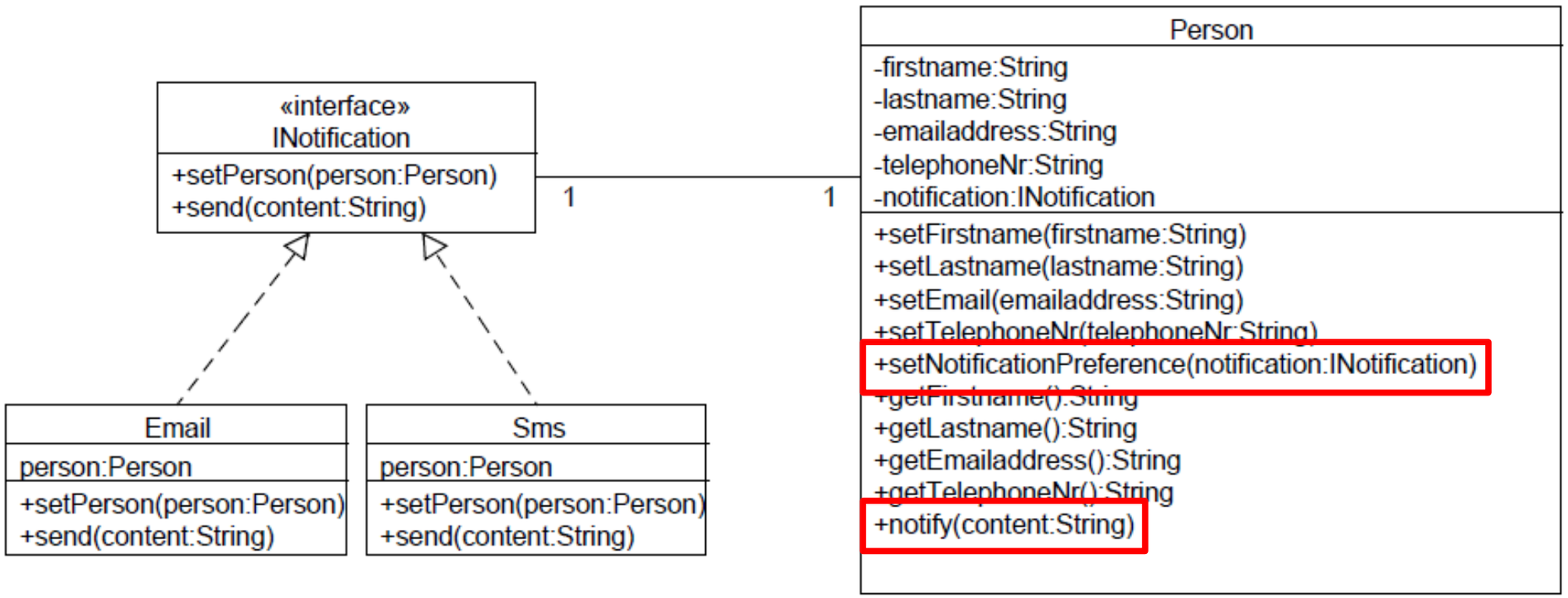


Behavioral Pattern - Strategy

Issue: Need to extend strategies at runtime

Example: **Notification strategy**

- Context object decides which strategy to use



Behavioral Pattern - Strategy

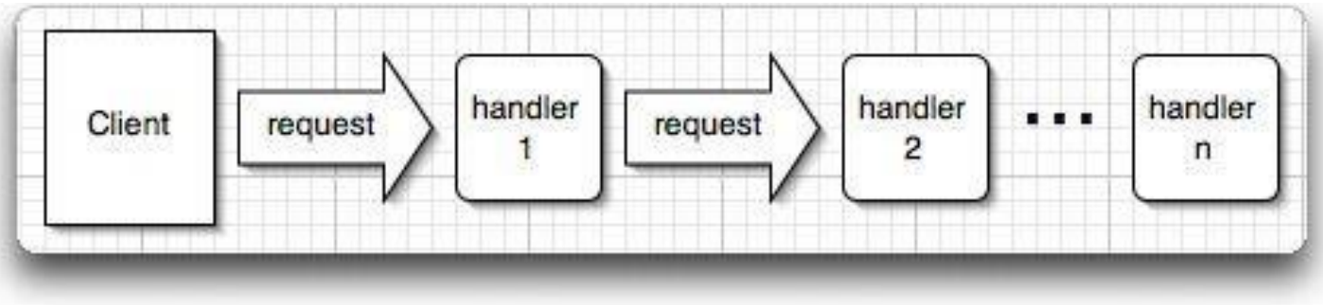
Code Example

```
class NotificationManager {
  public enum NotificationMethod {SMS, EMAIL};
  private List<Person> members;
  ...
  public void addMember(Person person,
            NotificationMethod notificationPref) {
    members.add(person);
    INotification notification;
    if (notificationPref == NotificationMethod.SMS)
    {
      notification = new Sms();
    } else {
      notification = new Email();
    }
    notification.setPerson(person);
    person.setNotificationPreference(notification);
  }

  public void sendNotifications(String message) {
    for (Person p : members) {
      p.sendMessage(message);
    }
  }
  ...
}
```

Behavioral Pattern - Chain of Responsibility

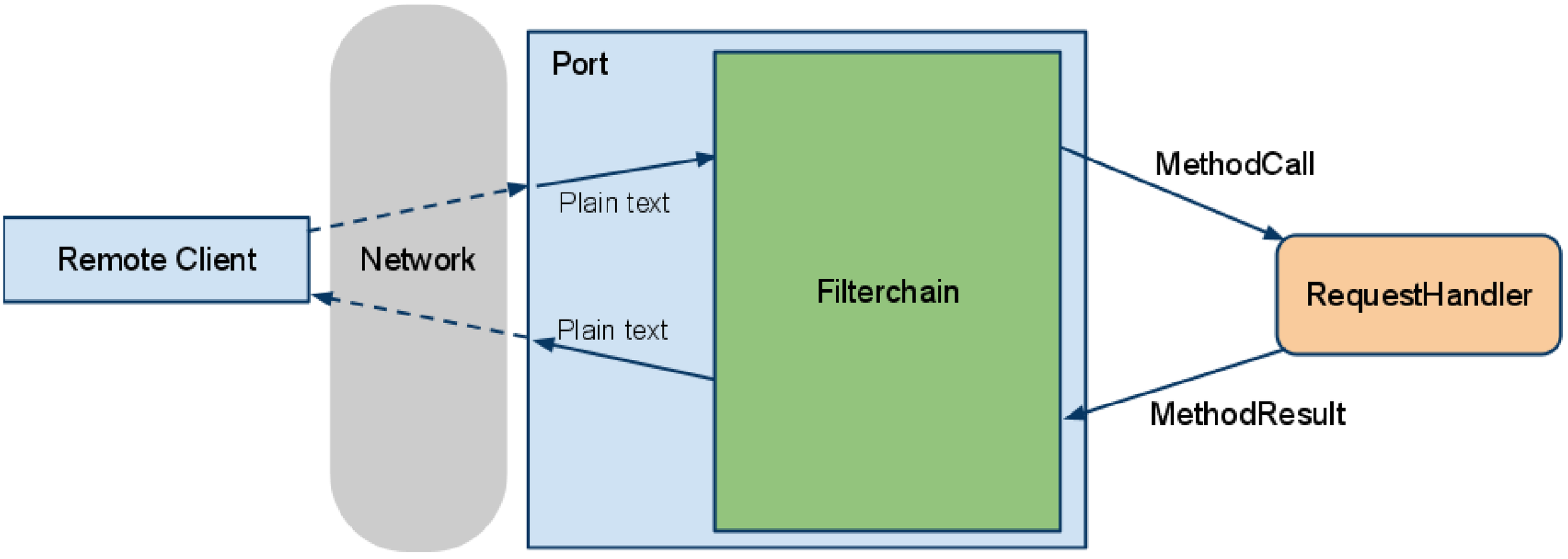
Issue: Improve loose coupling between a series of processing logic

- Chain of Objects
  - a source of command objects
  - a series of processing objects with logic capable of handling specific command objects



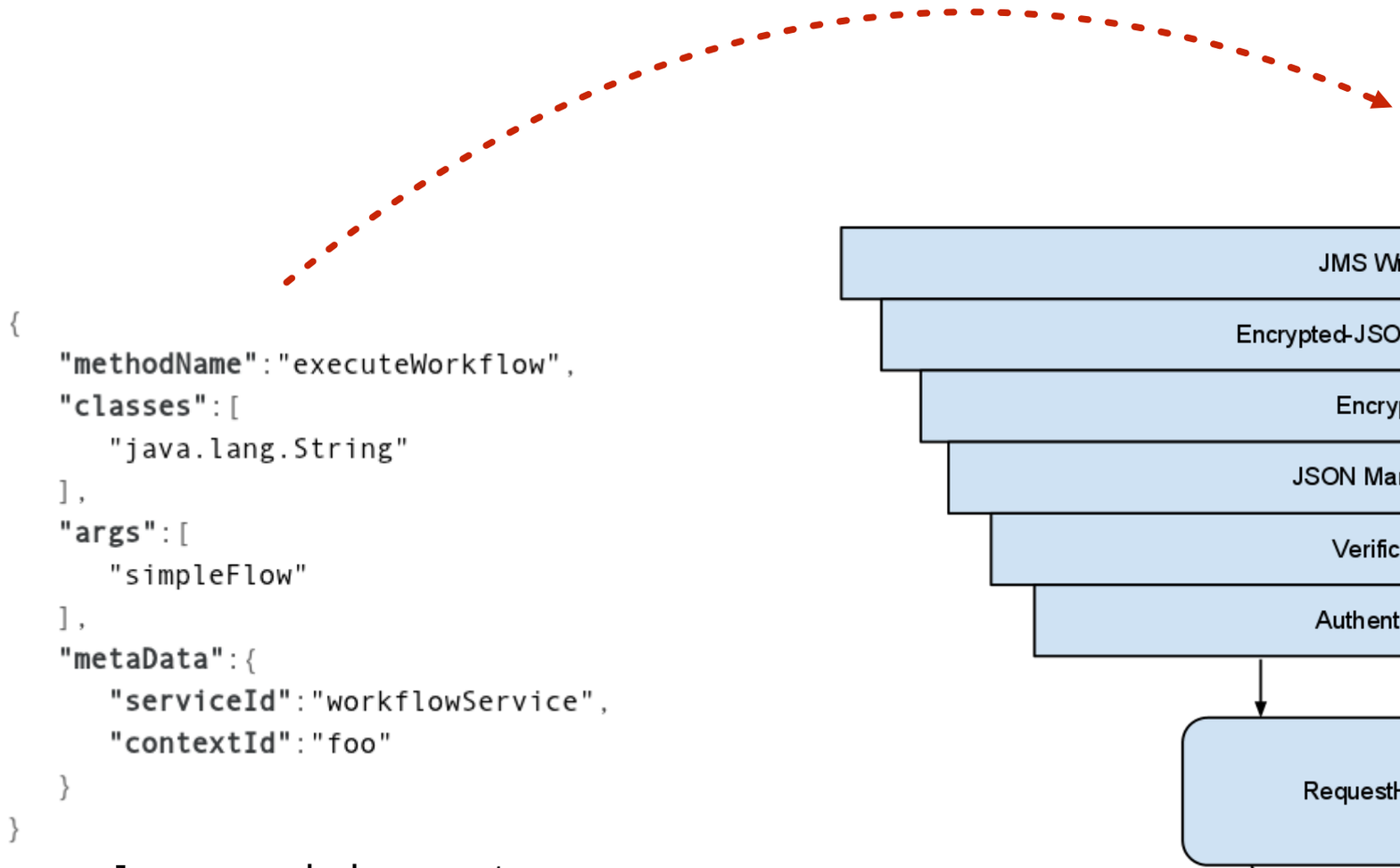
Behavioral Pattern - Chain of Responsibility

- Chain of Objects
  - a source of command objects
  - a series of processing objects with logic capable of handling specific command objects



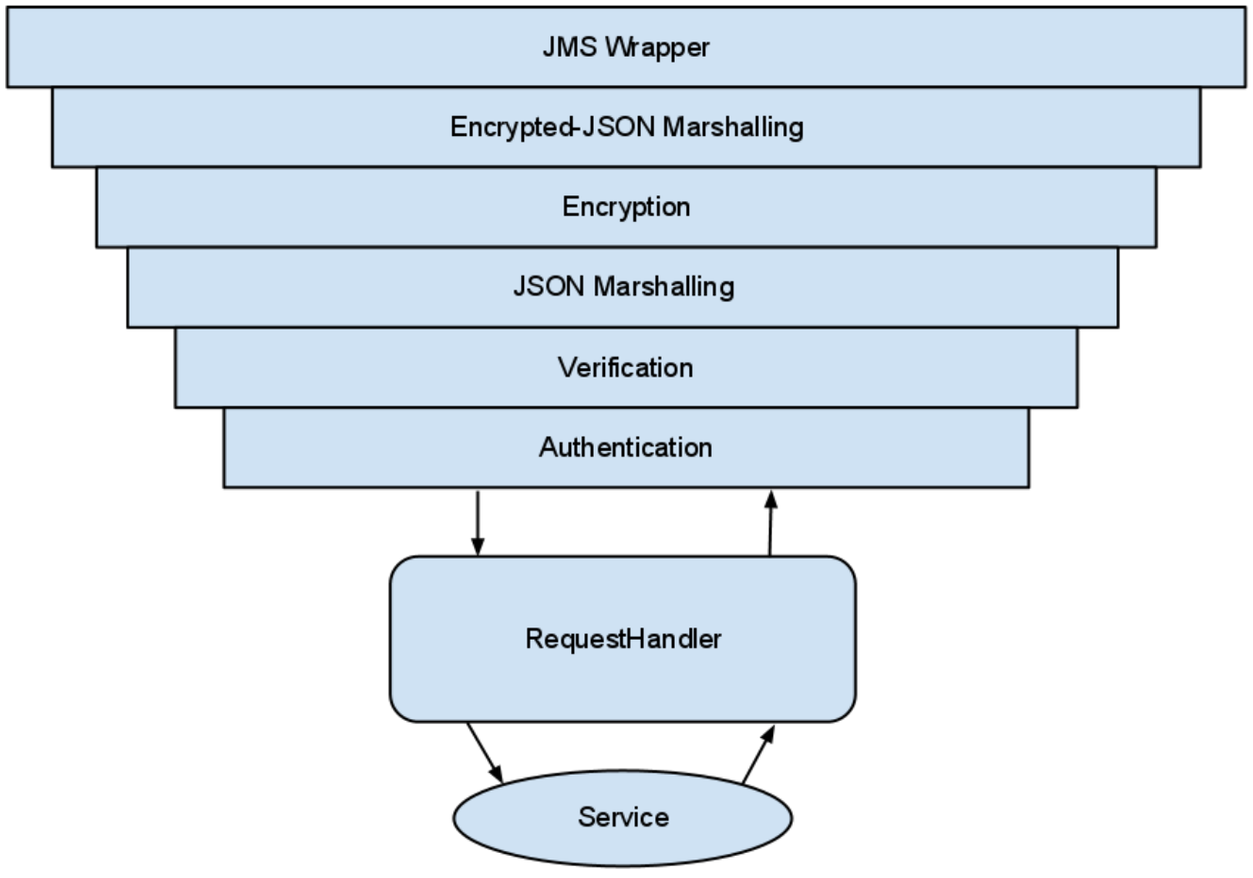
Behavioral Pattern - Chain of Responsibility

Example: **Remote service request**



```
{
   "methodName":"executeWorkflow",
   "classes":[
      "java.lang.String"
   ],
   "args":[
      "simpleFlow"
   ],
   "metaData":{
      "serviceId":"workflowService",
      "contextId":"foo"
   }
}
```

Json encoded request

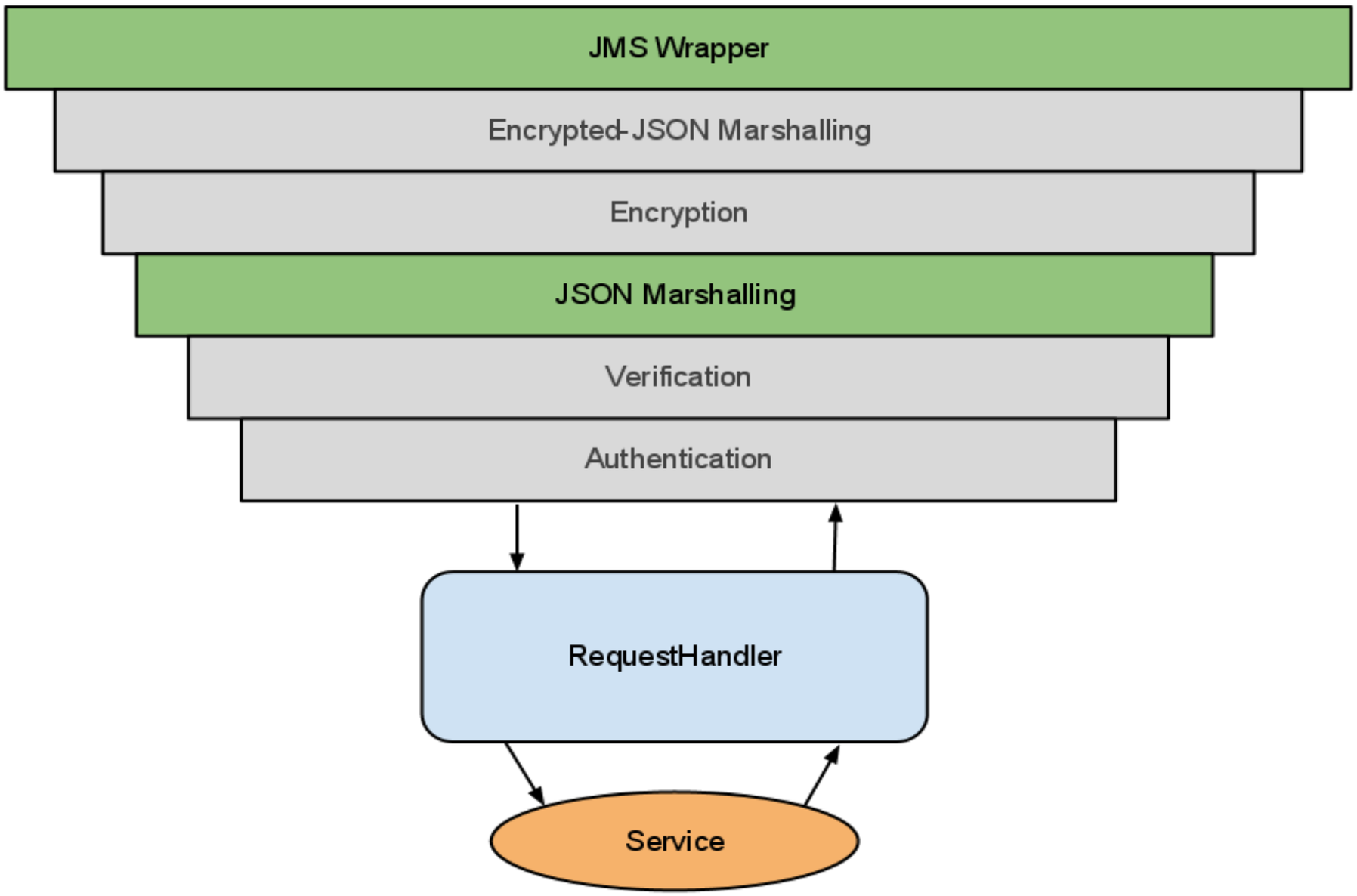


Behavioral Pattern - Chain of Responsibility

Example: **Remote service request**

```
 */
public class JsonMethodCallMarshalFilter extends AbstractFilterChainElement<String, String> {

    private FilterAction next;

    @Override
    public String doFilter(String input, Map<String, Object> metadata) throws FilterException {
        ObjectMapper objectMapper = JsonUtils.createObjectMapperWithIntroSpectors();
        MethodCallRequest call;
        try {
            call = objectMapper.readValue(input, MethodCallRequest.class);
            JsonUtils.convertAllArgs(call);
            MethodResultMessage returnValue = (MethodResultMessage) next.filter(call, metadata);
            return objectMapper.writeValueAsString(returnValue);
        } catch (IOException e) {
            throw new FilterException(e);
        }
    }

    @Override
    public void setNext(FilterAction next) throws FilterConfigurationException {
        checkNextInputAndOutputTypes(next, MethodCallRequest.class, MethodResultMessage.class);
        this.next = next;
    }

}
```

Example: **Remote service request**



Summary

- Industrial Use Case
- Engineering Service Bus
- Design patterns provide a structure in which problems can be solved.
  - Review different applications of one pattern
  - Gain experience
  - "code smells"

- Offering Topics
  - http://qse.ifs.tuwien.ac.at/topics.htm
  - felix.rinker@qse.ifs.tuwien.ac.at

How to gain experience

- Participate in open source projects, e.g.
  - OPS4J https://github.com/ops4j
  - Apache Projects https://projects.apache.org/projects.html
  - Google Summer of Code https://developers.google.com/open-source/gsoc/
  - …

- Build up your own technology radar
  - Martin Fowler: Catalog of Patterns of Enterprise Application Architecture https://martinfowler.com/eaaCatalog/
  - study Stack Overflow design pattern topics https://stackoverflow.com/questions/tagged/design-patterns

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