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Introduction to Design Patterns

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(Design) Patterns

A pattern describes...

- a problem which occurs over and over again in our environment,
- the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice.

(Christopher Alexander)

On Patterns...

- **Patterns are proven**
- Proven software practice
- Piece of literature
- Building block, with various abstraction levels:
  - *Idiom (Coplien, 1991)*
  - *Design Pattern (Gamma et al., 1995)*
  - *Architectural Pattern (Buschmann et al., 1996)*

Idioms

… are not (OO-) Design Patterns

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An **idiom** is a low-level pattern
(typically specific to a programming language).

- String copy in C
  (`s` and `d` are char arrays)

```
while (*d++=*s++);
```

Example

An **idiom** is a low-level pattern
(typically specific to a programming language).

Example

- Lazy instantiation of Singletons in Java
  (Double-checked Locking Idiom)

```
private static Device device = null;
public static Device instance() {
   if (device == null) {
      synchronized (Device.class) {
         if (device == null) {
            device = new Device();
   }  }  }
   return device;
}
```

Template Method

A first Design Pattern

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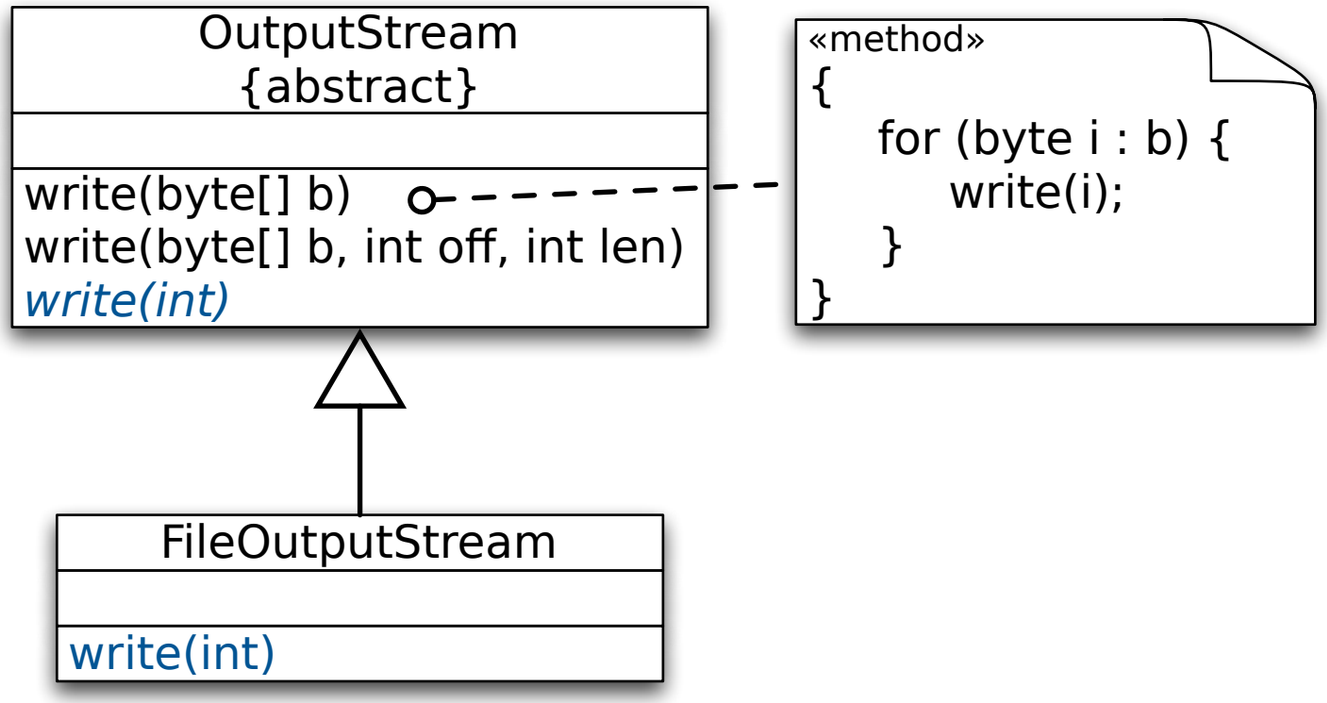
The Template Method Pattern

Design Goal

- We want to implement an algorithm such that certain (specific) parts can be adapted / changed later on.

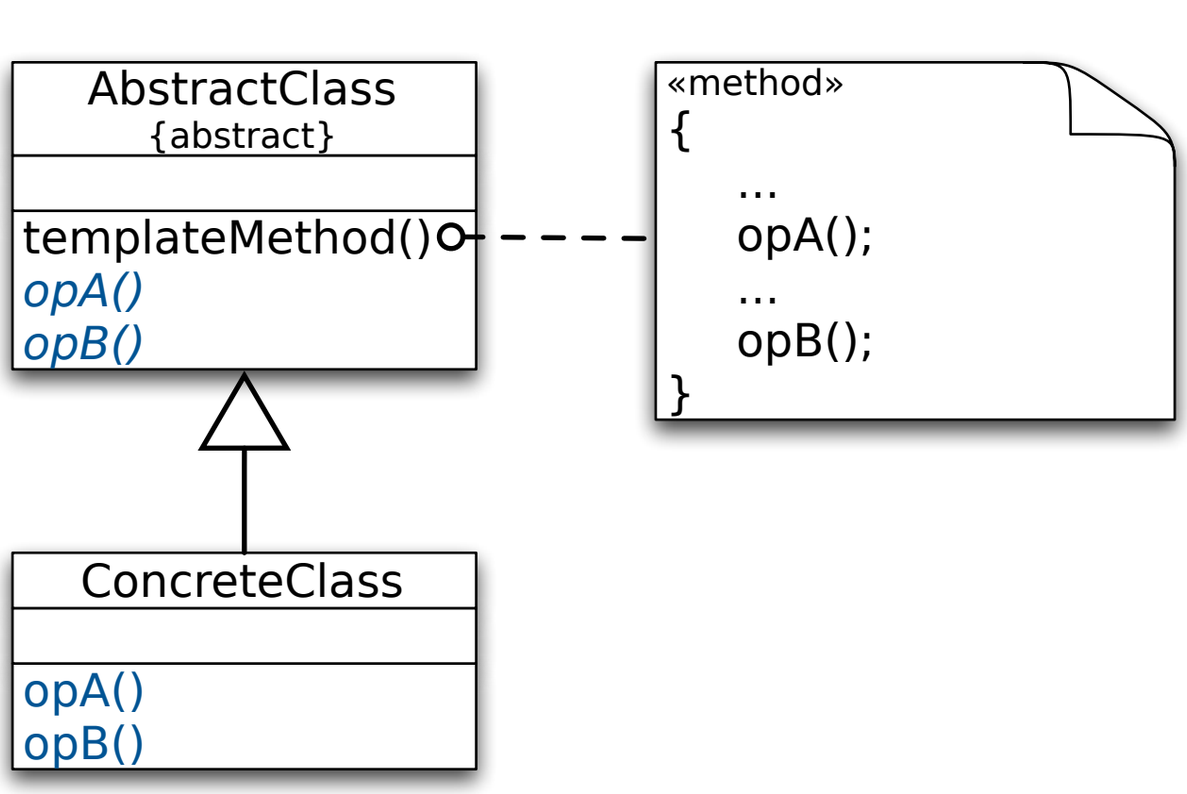
The Template Method Pattern

- Define a skeleton of an algorithm in an operation, but defer some steps to subclasses
- Often found in frameworks and APIs



The Template Method Pattern

- Use the Template Method Pattern to ….
  - separate variant and invariant parts
  - avoid code duplication in subclasses; the common behavior is factored and localized in a common class
  - control subclass extensions



The template method is the method that defines the algorithm using abstract (and concrete) operations.

Besides, abstract operations (must be overridden) it is possible to define hook operations (may be overridden).

Design Patterns - Motivation

- Designing reusable, extensible software is hard
- Novices are overwhelmed
- Experts draw from experience
- Some design solutions reoccur
- Understanding reoccurring solutions has several facets:
  - Know when to apply
  - Know how to establish it in a generic way
  - Know the consequence (trade-offs)

Architectural Patterns

… are not Design Patterns

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Architectural patterns help to specify **the fundamental structure of a software system**, or important parts of it.

- Architectural patterns have an important impact on the appearance of concrete software architectures
- Define *a system's global properties*, such as …
  - how distributed components cooperate and exchange data
  - boundaries for subsystems
- The *selection of an architectural pattern is a fundamental design decision*; it governs "every" development activity that follows

Architectural patterns help to specify the fundamental structure of a software system, or important parts of it.

Architectural Patterns

- Pipes and Filters
- Broker Pattern
- MVC
- Broker
- …

Often, it is not sufficient to choose just one architectural pattern; instead it is necessary to combine several architectural patterns.

Example: Model-View Controller (MVC)

The MVC pattern describes a fundamental structural organization for interactive software systems

- The model contains the core functionality and data
  The model is independent of output representations or input behavior.
- The user interface is comprised of:
  - Views that display information to the user
    The view obtains the data from the model.
  - Controllers that handle user input
    Each view has a controller. A controller receives input. The events are then translated to service requests for the model or the view. All interaction goes through a controller.

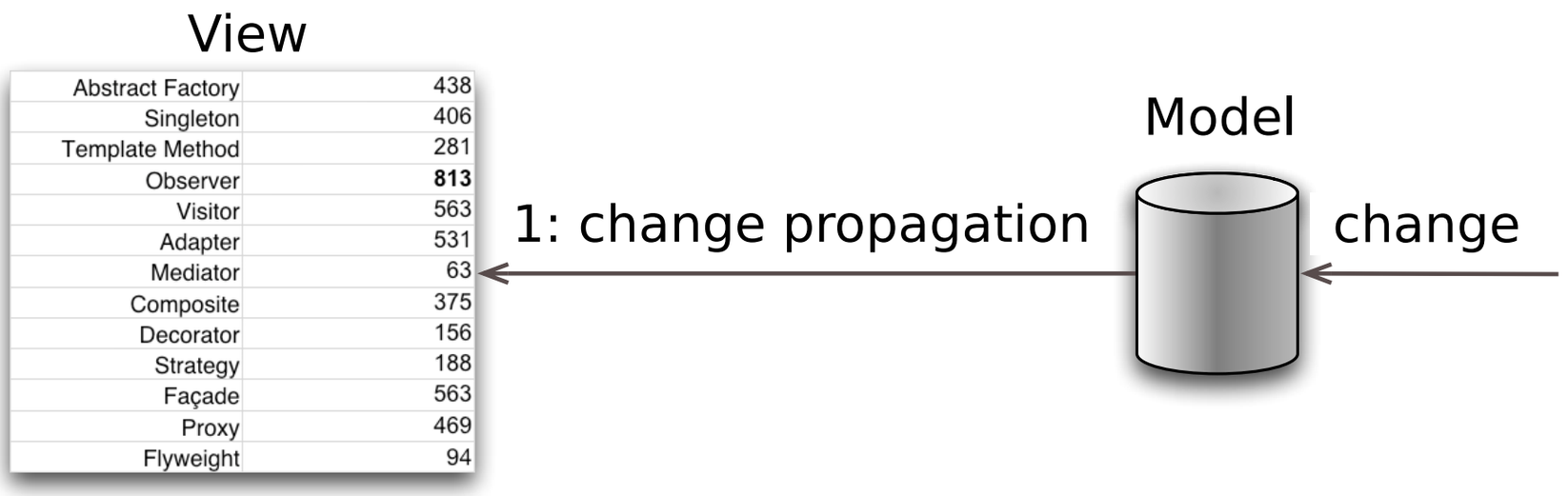
Example: Model-View Controller (MVC) Change Propagation

- A change propagation mechanism ensures consistency between the user interface and the model.
  (The change-propagation mechanism is usually implemented using the Observer pattern / the Publisher-Subscriber pattern.)

Basic Idea:

A view registers itself with the model.

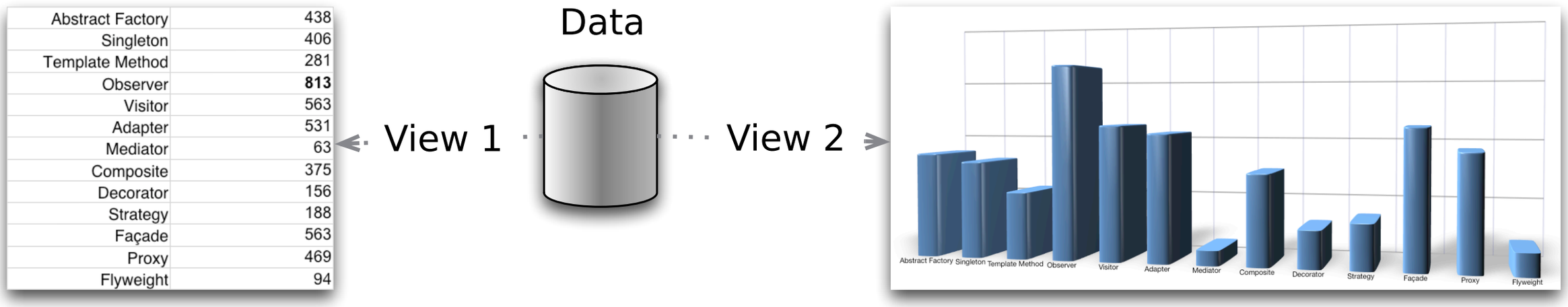
If the behavior of a controller depends on the state of the model, the controller registers itself with the change propagation mechanism.



Example: Model-View Controller (MVC) Change Propagation

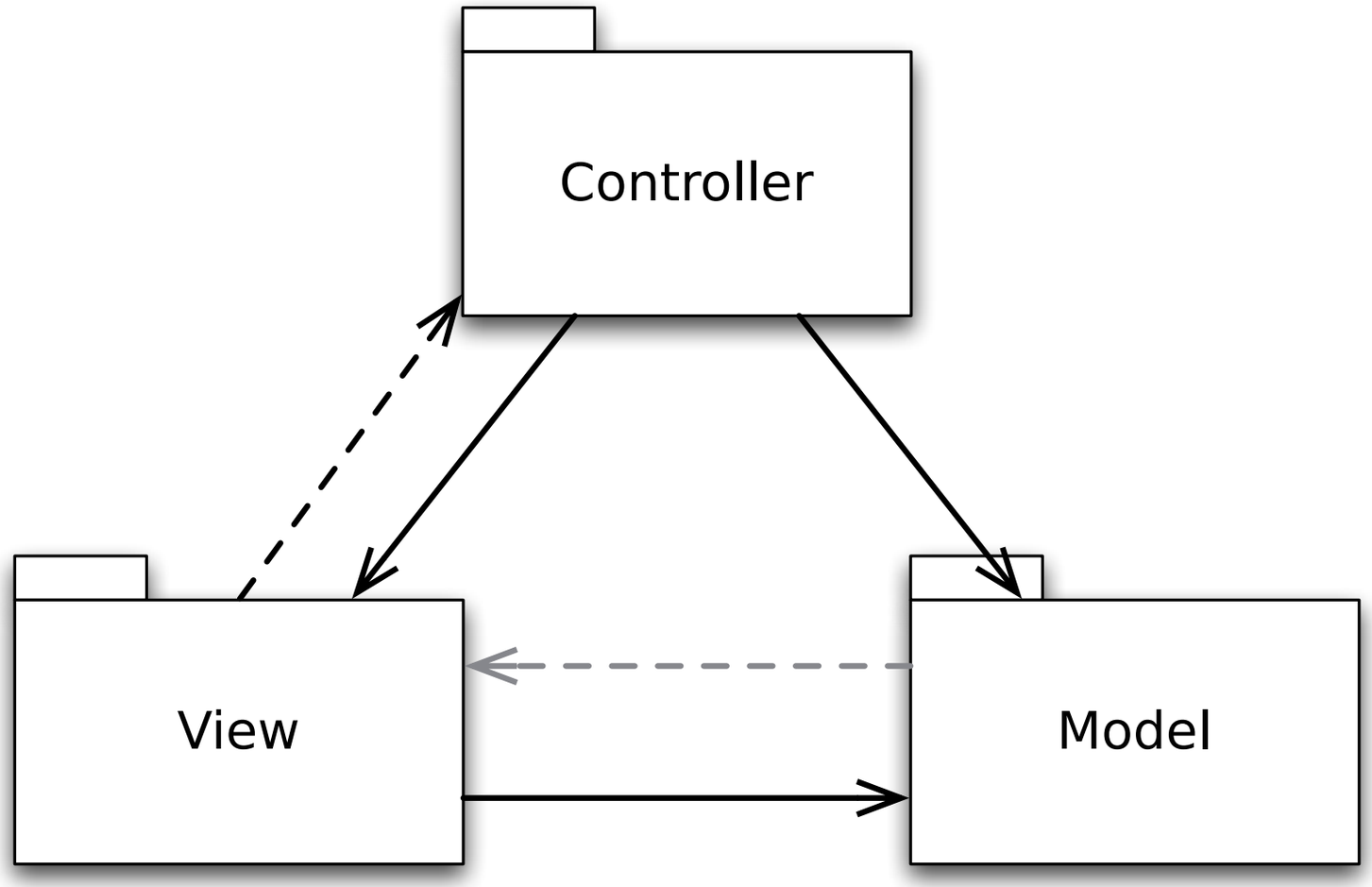
Use the MVC pattern for building interactive applications with a flexible human-computer interface. When...

- the same information should be presented differently (in different windows...)
- the display and behavior of the application must reflect data manipulations immediately
- porting the UI (or changing the L&F) should not affect code in the core of the application



Example: Model-View Controller (MVC) Structure

While the Controller and the View are directly coupled with the Model, the Model is not directly coupled with the Controller or the View.



Example: Model-View Controller (MVC) Liabilities

- Increased complexity
  Using separate view and controller components can increase complexity without gaining much flexibility
- Potential for excessive number of updates
  Not all views are always interested in all changes.
- Intimate connection between view and controller

(Liabilities =dt. Verantwortlichkeiten / Verbindlichkeiten)

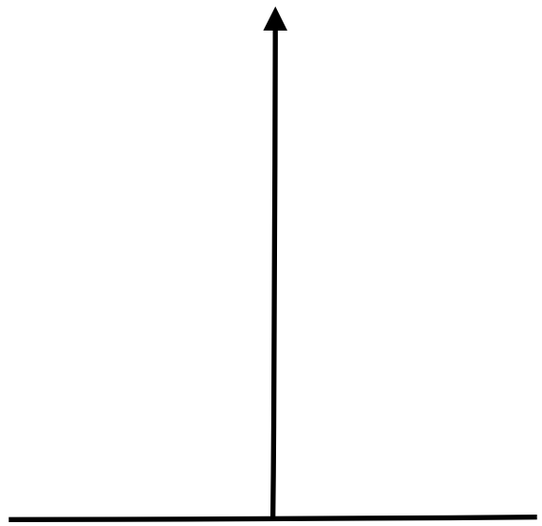
Architectural Patterns
Recommended Resources

- **Pattern-Oriented Software Architecture - A System of Patterns**; Frank Buschmann, Regine Meunier, Hans Rohnert, Peter Sommerlad, Michael Stal; Wiley 1996
- **Design Patterns**; Gamma et al.
- **Patterns of Enterprise Application Architecture**; Martin Fowler; Addison Wesley 2003

Properties of
(Design) Patterns

Design Patterns - Benefits

- Systematic (software-)development:
  - Documenting expert knowledge
  - Use of generic solutions
  - **Raising the abstraction level**



Design Patterns - Essentials

- a pattern has a name
- the problem has to reoccur to make the solution relevant in situations outside the immediate one
- it has to be possible to tailor the solution to a variant of the problem

A Design Pattern describes a solution for a problem in a context.

(to tailor =dt. anpassen)

Essential Parts of Patterns

1. **Pattern Name**
   A short mnemonic to increase your design vocabulary.
2. **Problem**
   Description when to apply the pattern (conditions that have to be met before it makes sense to apply the pattern).

3. **Solution**
   The elements that make up the design, their relationships, responsibilities and collaborations.
4. **Consequences**
   Costs and benefits of applying the pattern. Language and implementation issues as well as impact on system flexibility, extensibility, or portability.
   The goal is to help understand and evaluate a pattern.

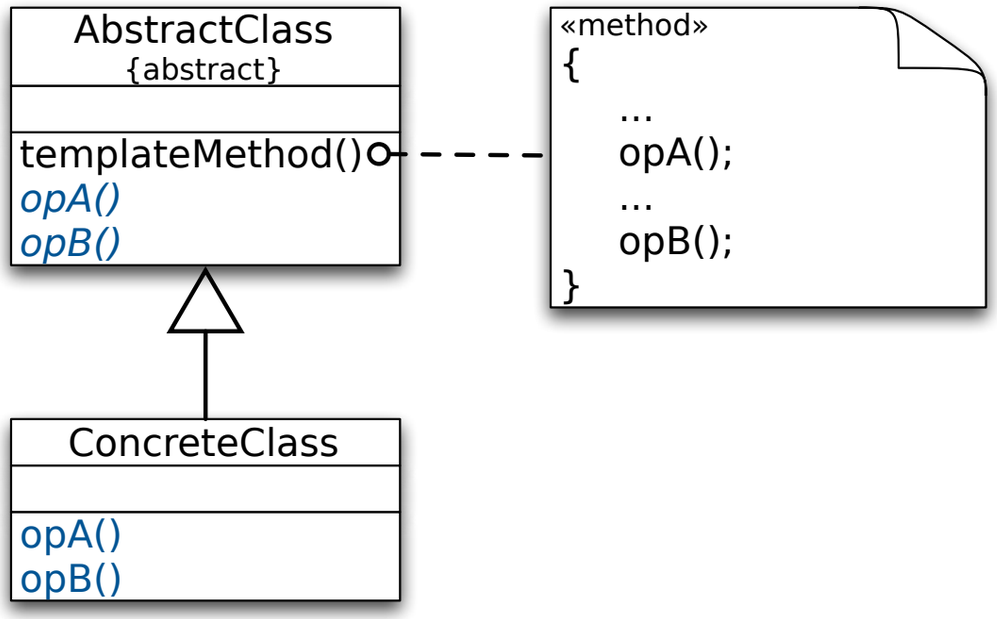
Template for Design Patterns

(For Design Patterns as described by Gamma et al., 1995)

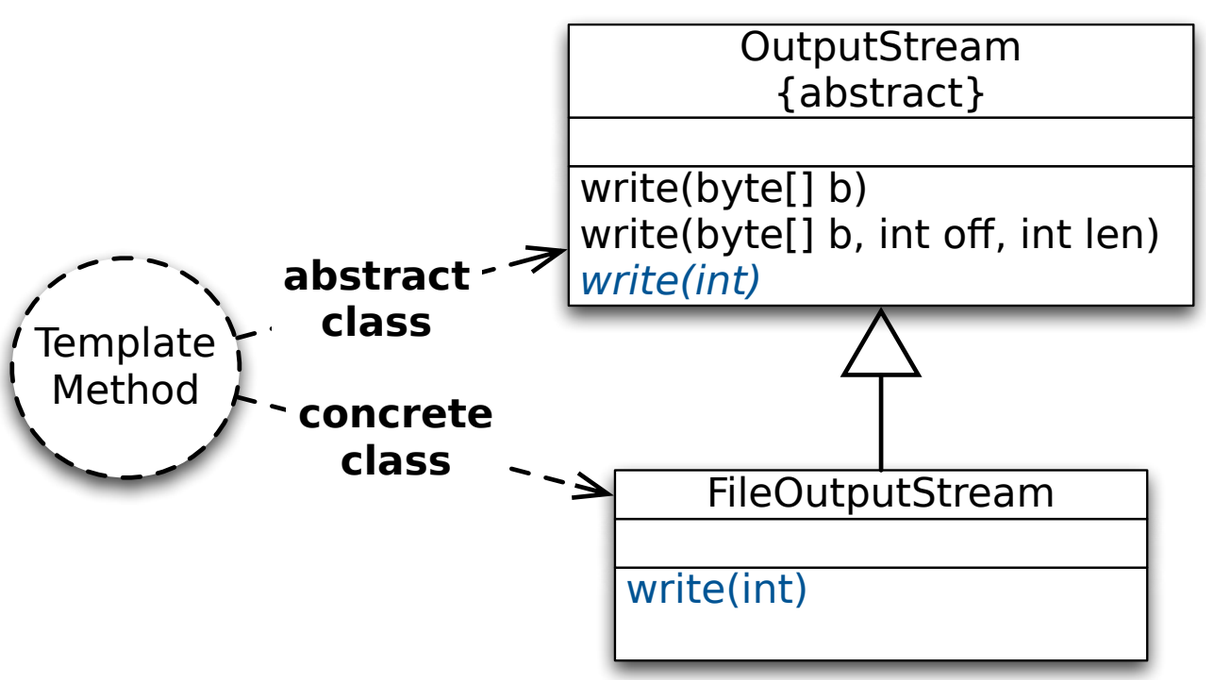
1.	▶ Name ▶ Intent
2.	▶ Motivation ▶ Applicability
3.	▶ Structure ▶ Participants ▶ Collaboration ▶ Implementation
4.	▶ Consequences
5.	▶ Known Uses ▶ Related Patterns

To document a used design pattern use the participant names of the pattern to specify a class' role in the implementation of patterns.

Template Method Pattern



Use of the Template Method Pattern in Java



Levels of Consciousness for a Design Pattern

1. Innocence
2. Known tricks
3. Competent trick application
4. Applicability & consequences known
5. Wide knowledge of patterns & their interaction
6. **Capable of capturing knowledge into literate form**

Design Patterns Serve Multiple Purposes

Elements of Reusable Software	patterns foster reusability
Reuse of Design	rather than code
Communication	design vocabulary
Documentation	information chunks
Language Design	high level languages
Teaching	passing on culture

Patterns enable the construction of high-quality software architectures.

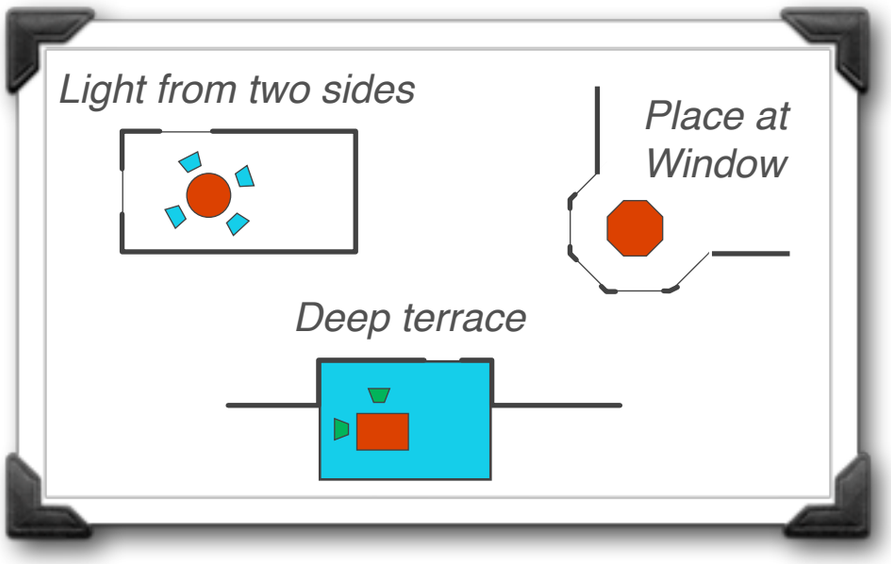
A **software design pattern** describes...

- a commonly recurring structure of interacting software components
- that solve a general software design problem

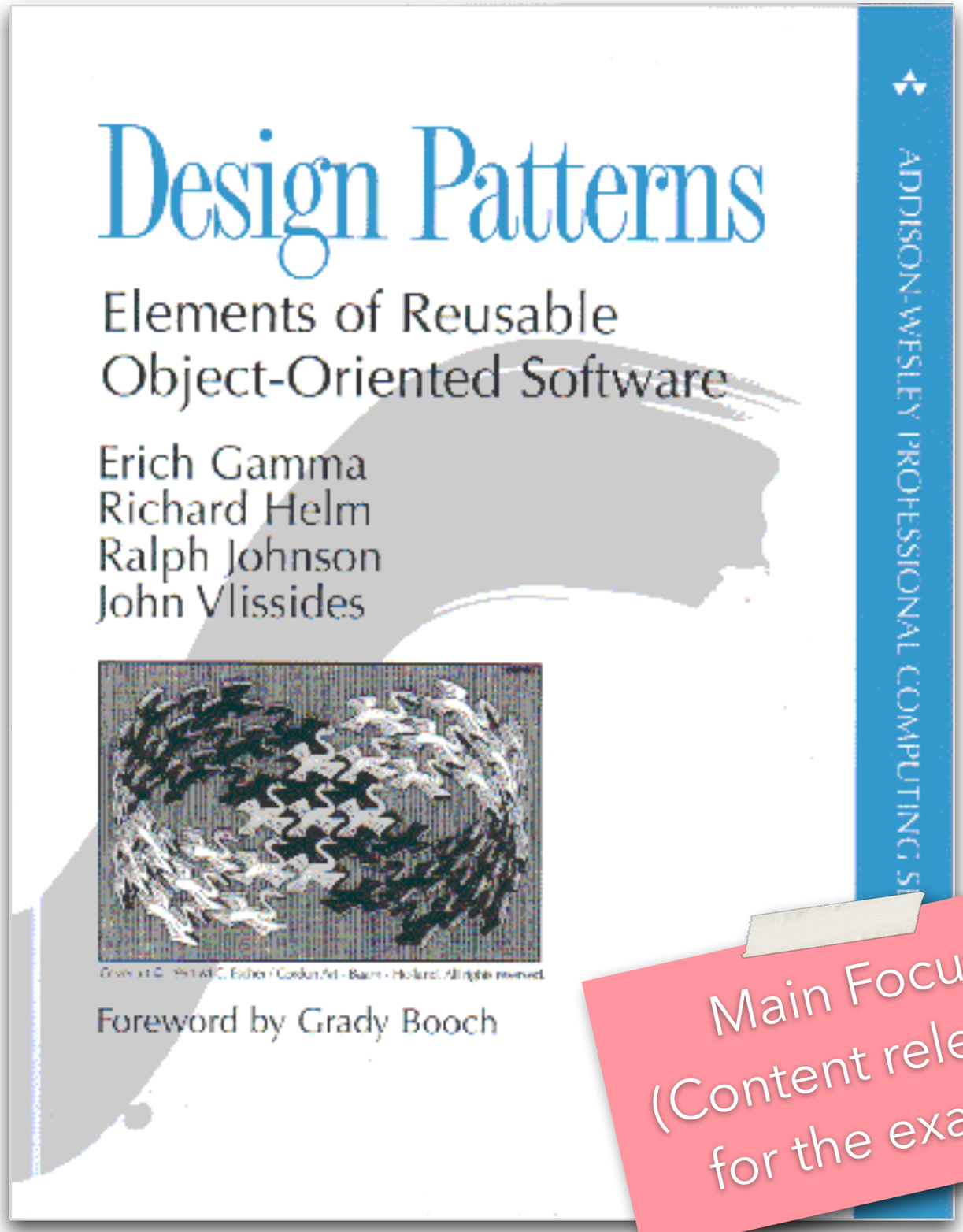
within a particular context.

Design Patterns - Occurrences

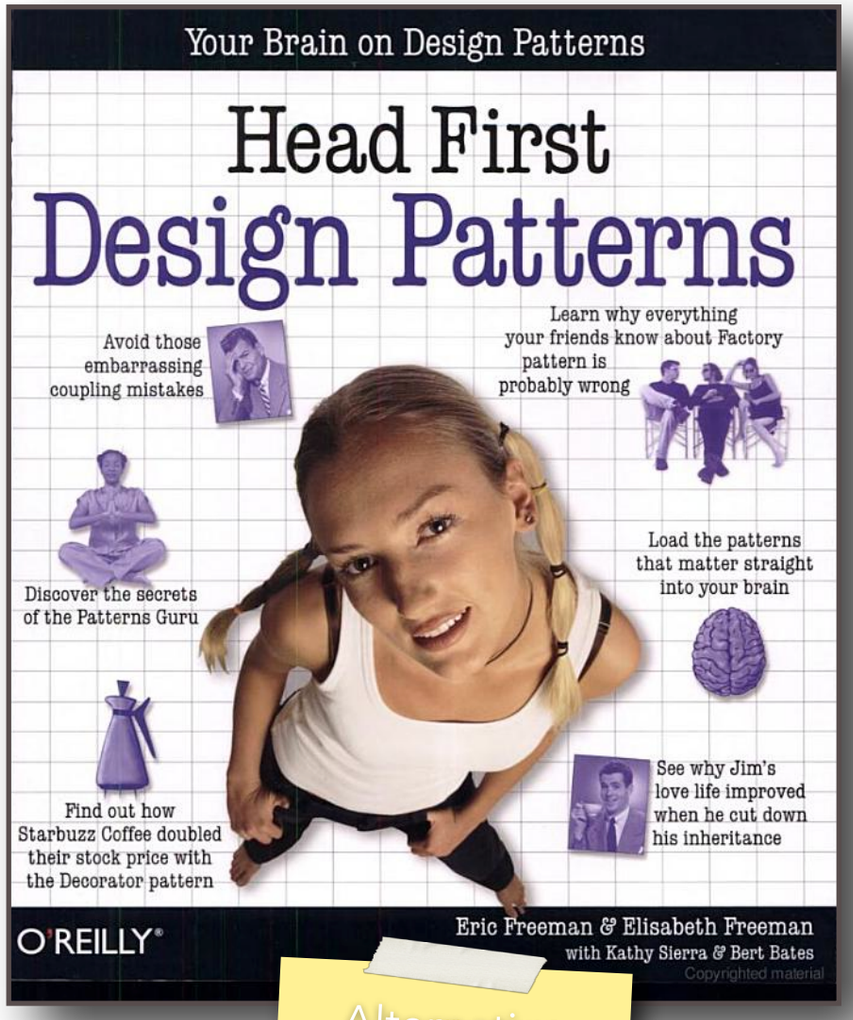
chess	from rules to expertise
literature	oldest reference
agriculture	wisdom vs. science
architecture	pioneering work
software design	



Patterns in Architecture



Main Focus
(Content relevant
for the exam!)



Alternative
Book

(Design Patterns =dt. Entwurfsmuster)

Summary

The goal of this lecture is to enable you to systematically carry out small(er) software projects that produce quality software.

- Idioms, Design Patterns and Architectural Patterns help you to solve recurring problems (at different abstraction levels) and to immediately understand the benefits and tradeoffs.
- Patterns enable you to talk about the design of your application at a higher abstraction level.