Introduction to Software Engineering

Introduction to 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)

“Aggressive disregard for originality.”
Idioms

... are not (OO-) Design Patterns
An **idiom** is a low-level pattern (typically specific to a programming language).

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

```c
while (*d++=*s++);
```
An **idiom** is a low-level pattern (typically specific to a programming language).

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

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

Requires Java 6 or newer to work correctly!
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
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.

- 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.

More on this topic: Enterprise Application Design
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.
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)

Applicability

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

(Liabilities = dt. Verantwortlichkeiten / Verbindlichkeiten)

- **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**
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
Systematic (software-)development:

- Documenting expert knowledge
- Use of generic solutions
- Raising the abstraction level
A Design Pattern describes a solution for a problem in a context.

- 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
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

```
AbstractClass
    {abstract}
    templateMethod()
    opA()
    opB()

ConcreteClass
    opA()
    opB()
```

Use of the Template Method Pattern in Java

```
OutputStream
    {abstract}
    write(byte[] b)
    write(byte[] b, int off, int len)
    write(int)

FileOutputStream
    write(int)
```

Abstract class

Concrete class

Template Method
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

<table>
<thead>
<tr>
<th>Elements of Reusable Software</th>
<th>patterns foster reusability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reuse of Design</td>
<td>rather than code</td>
</tr>
<tr>
<td>Communication</td>
<td>design vocabulary</td>
</tr>
<tr>
<td>Documentation</td>
<td>information chunks</td>
</tr>
<tr>
<td>Teaching</td>
<td>passing on culture</td>
</tr>
<tr>
<td>Language Design</td>
<td>high level languages</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>chess</th>
<th>from rules to expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>literature</td>
<td>oldest reference</td>
</tr>
<tr>
<td>agriculture</td>
<td>wisdom vs. science</td>
</tr>
<tr>
<td>architecture</td>
<td>pioneering work</td>
</tr>
</tbody>
</table>

software design

Patterns in Architecture
Design Patterns

Main Focus
(Content relevant for the exam!)

Alternative Book
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.