Guidelines for Using Aspects in Product Lines

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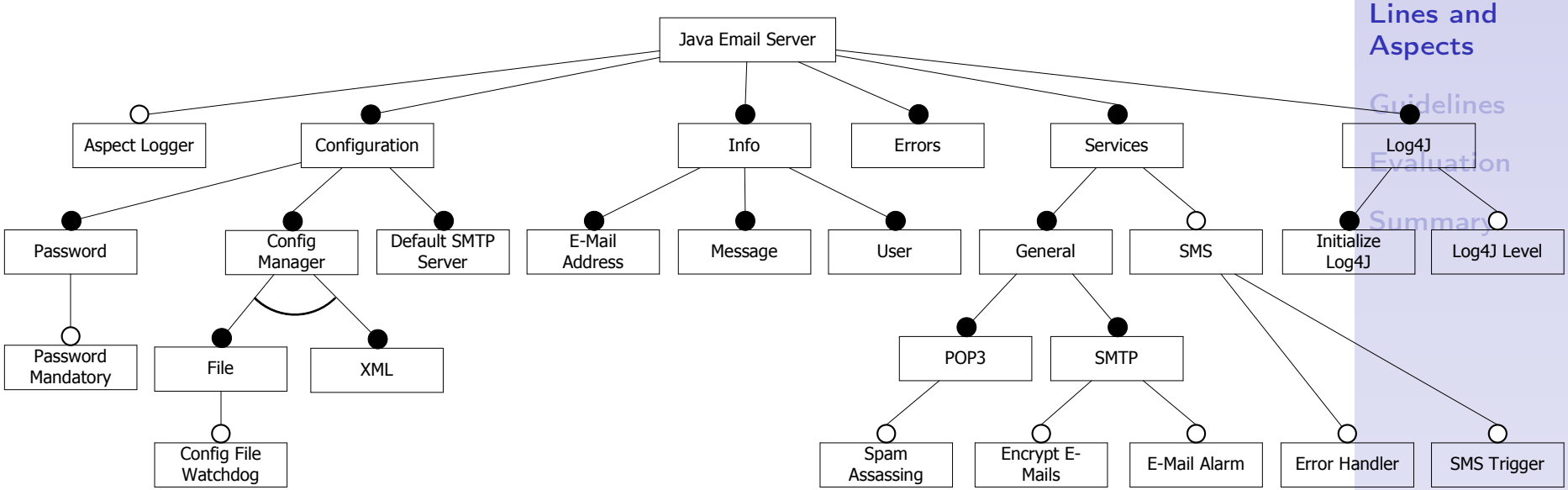
SAMI 2010, January 28–30, 2010, Herľany, Slovakia

Overview

Software Product Lines

- An organized approach to software reuse
- Successful because it's focused on a particular domain
- Common and variable feature
- Configuration: selection of variable features

Feature Model



Constraints:

E-Mail Alarm requires SMS

Configuration and Crosscutting

- Product line development is complicated and represents a large investment
- In part, this is due to crosscutting concerns
- A crosscutting problem affects configuration: crosscutting features cannot be easily incorporated nor taken out once they have been incorporated

Aspects

- Advanced software decomposition and composition approach: decomposition into multiple views developed separately and composed as needed
- Commonly denoted as aspect-orientation
- PARC AOP and AspectJ prevail: untangling crosscutting concerns
- But there are quite different yet still aspect-oriented approaches

Aspect

- The main construct in PARC aspect-oriented programming is an aspect
- Main parts of an aspect:
  - Pointcuts: specifying the join points the aspect affects
  - Advices: implementing the affecting functionality
  - Inter-type declarations: introducing new fields and methods, inheritance relationship, warnings, compile errors, softened exceptions, and annotations into types

How Can Aspect-Orientation Help

- Probably impossible to formulate strict rules of aspect-oriented programming application to product lines
- But recommendations on its use in the form of guidelines that represent expert knowledge can be given

Guideline Sources

- Experience reported in peer reviewed scientific work
- But also in informal contributions to discussion forums
- Available, but not in a compact and ready to use form
- An idea: extract the knowledge and express it as guidelines
- A lightweight, non-restrictive approach

Guideline Form

- The idea of guidelines is close to patterns
- We applied Coplien's form of pattern description:
  - Short name
  - Name
  - Context
  - Problem
  - Forces
  - Solution
  - Example
  - Discussion
- Not necessary to avoid difference in recommendations at all costs
- But the guideline should accommodate to them and eventually provide some possibilities of combining even the differing guidelines

The Guidelines (1)

- **Implementing Features of Refactored Legacy Applications**:
  The aspects are unsuitable for implementing features of refactored legacy applications.
- **Implementing Mandatory Features with no Crosscutting Concerns**:
  Do not use aspects in mandatory features if there are no crosscutting concerns.
- **Code Reduction in Homogenous Crosscutting Concerns**:
  The aspects are suitable for reduction of replicated code in homogenous crosscutting concerns.

The Guidelines (2)

- **Transforming a Mandatory Feature into Alternative Features**:
  Do not use aspects in transforming a mandatory feature into alternative features.
- **Implementing Features which Share no Code**:
  Use aspects in implementing features which share no code and which have crosscutting concerns.

An Example Guideline (1)

- Code Reduction in Homogenous Crosscutting Concerns (introduced in the paper)
- The aspects are suitable for reduction of replicated code in homogenous crosscutting concerns
- Aspects reduce replicated code in code with homogenous crosscutting concerns[1]
- Homogenous crosscutting concerns address multiple join points with a single piece of advice
- Heterogeneous crosscutting concerns, in contrast, address multiple join points each with a different piece of advice
- Homogeneity lies in a consistent application of the same or very similar policy in multiple places

[1] S. Apel, T. Leich, and G. Saake. Aspectual mixin layers: aspects and features in concert. In *Proc. of 28th International Conference on Software Engineering, ICSE 2006*, pages 122–131, Shanghai, China, 2006. ACM Press.

An Example Guideline (2)

- *Context:* the same concern repeated across different modules in a product line
- *Problem:* hard to maintain and keep consistent the code scattered across the application
- *Forces:* need to modularize the crosscutting concerns and represent each one by a single feature for ease of maintenance and configurabilty, but the conventional approach does not provide mechanisms for this
- *Solution:* use aspects to factor out homogenous crosscutting concerns and implement them in separate advices

A Code Reduction Example

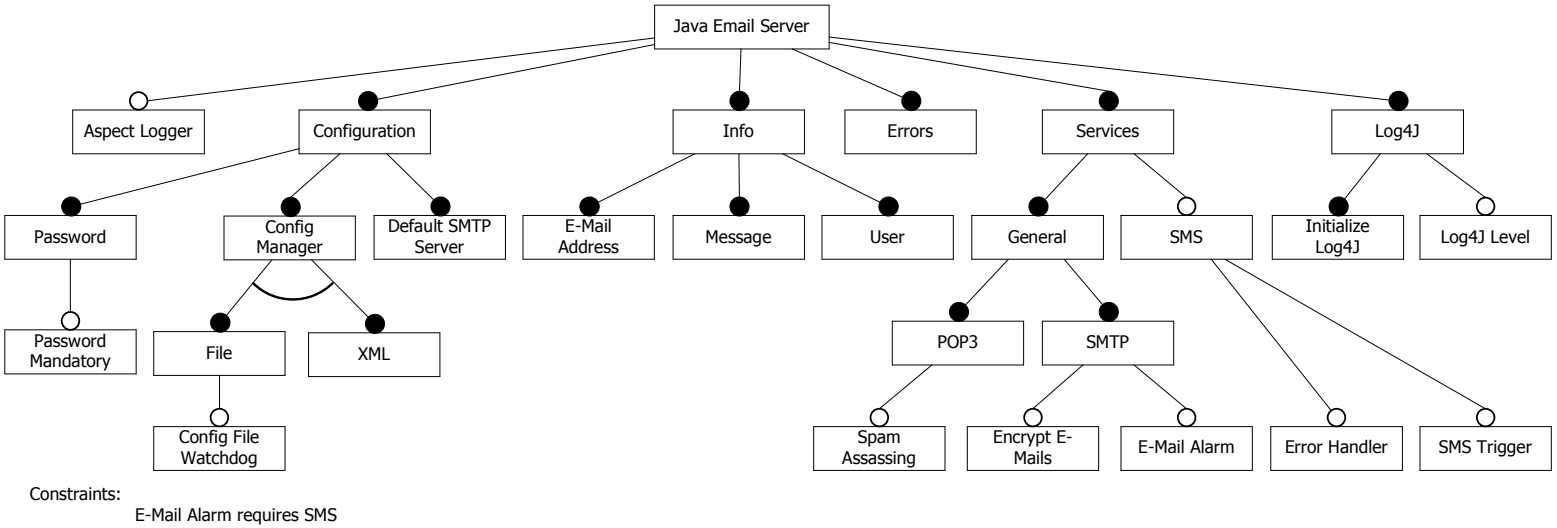
- Applicable to logging, tracing, exception handling, etc.
- An aspect affecting a set of otherwise unrelated methods using one coherent advice:

```
public aspect Homogenous {
    pointcut accessAuthorization(): call(...);
    pointcut accessDemilitarizedZone(): call(...);
    pointcut accessCommunicationInterfaces(): call(...);
    pointcut accessApplication(): call(...);

    before(): accessAuthorization() || accessDemilitariziedZone() ||
        accessCommunicationInterfaces() || accessApplication() {
        System.out.println("Accessing " + thisJoinPoint);
    }
}
```

Evaluation

- Evaluation performed on two product line implementations: an object-oriented and aspect-oriented one
- Based on the Java Email Server application[2]
- 4500 line of code, 22 classes, and several configuration files



[2] http://www.ericdaugherty.com/java/mailserver/

Metrics Applied (1)

- Scope of changes:
  - Lines of Code (LOC)
  - Number of Affected Classes (NAC)
- Quality of code:
  - Weighted Operations in Module (WOM)
  - Depth of Inheritance Tree (DIT)
  - Number of Children (NOC)
  - Crosscutting Degree of an Aspect (CDA)
  - Coupling of Method Call (CMC)
  - Coupling of Field Access (CFA)
  - Coupling between Modules (CBM)
  - Response for a Module (RFM)
  - Lack of Cohesion in Operations (LCO)

Metrics Applied (2)

- Package dependencies
  - Number of Types (NOT)
  - Abstractness (A)
  - Afferent Couplings (Ca)
  - Efferent Couplings (Ce)
  - Modified Efferent Couplings (Ce)
  - Instability (I)

Evaluation Results

- Numerical values of metrics available in the paper
- Implementing Features of Refactored Legacy Applications
  - Code with aspects shows similar level of coupling
- Implementing Mandatory Features with no Crosscutting Concerns
  - Aspect may obscure the code comprehension
  - No significant gain in LOC with aspects
- Code Reduction in Homogenous Crosscutting Concerns
  - A significant LOC gain with aspects
- Transforming a Mandatory Feature into Alternative Features
  - Both aspect-oriented and object-oriented approach add comparable number of LOC when used for adding new alternative feature
- Implementing Features which Share no Code
  - Lower method call coupling for most classes achieved with aspects

Summary

- An approach to expressing independently applicable guidelines about using aspect-oriented programming in product line development
- Evaluation performed on two product line implementations, an object-oriented and aspect-oriented one
- Results are in favor of the guidelines
- Further work
  - Identification of further guidelines
  - Evaluation of guidelines with respect to other aspect-oriented languages