Multi-Paradigm Design with Feature Modeling in Aspect-Oriented Software Development

Erasmus Mobility at Lancaster University

Lecture 3

Valentino Vranić

Institute of Informatics and Software Engineering
Faculty of Informatics and Information Technologies
Slovak University of Technology
Bratislava, Slovakia
vranic@fiit.stuba.sk
http://fiit.stuba.sk/~vranic/

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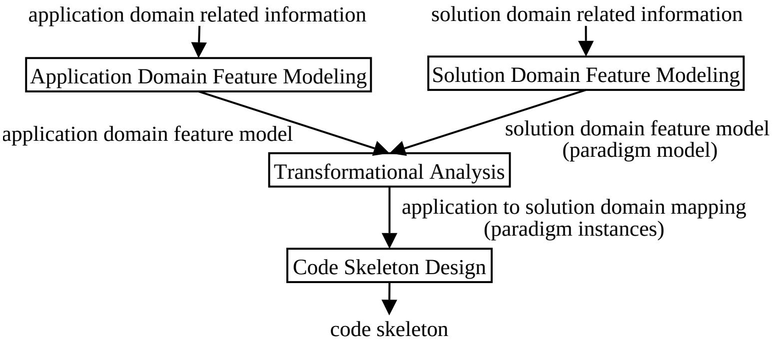
Overview

Introduction

- Notion of paradigm[1]
  - large-scale view—traditional (object-oriented programming, functional programming, etc.); imprecise
  - small-scale view—paradigms as configurations of commonality and variability (map to directly to language mechanisms)
- Programming languages are often categorized according to (large-scale) paradigms they support
- Multi-paradigm languages: are there any other?
- Multi-paradigm design: how to select a paradigm appropriate for the problem being solved
- Multi-paradigm design with feature modeling for AspectJ

[1] V. Vranić. Towards multi-paradigm software development. Journal of Computing and Information Technology (CIT), 10(2): 133-147, 2002.

Multi-Paradigm Design with Feature Modeling

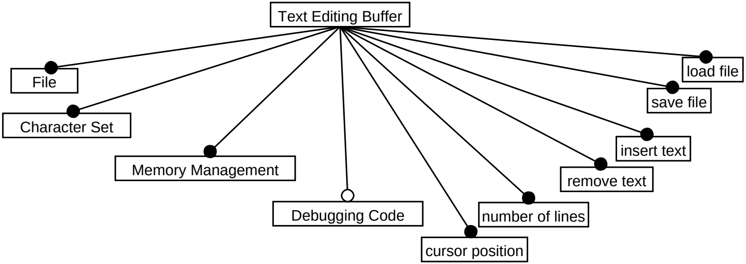


Feature Modeling

- Captures connections among features and variability
- Feature model: a set of feature diagrams plus additional information
- Based on the notions of *domain*, *concept*, and *feature*
  - Features: common and variable
  - Concept instances: concept specializations
- Various notations exist, e.g. FODA, ODM, or Czarnecki-Eisenecker
- Notation used here is based on Czarnecki-Eisenecker feature modeling adapted to multi-paradigm design[2]

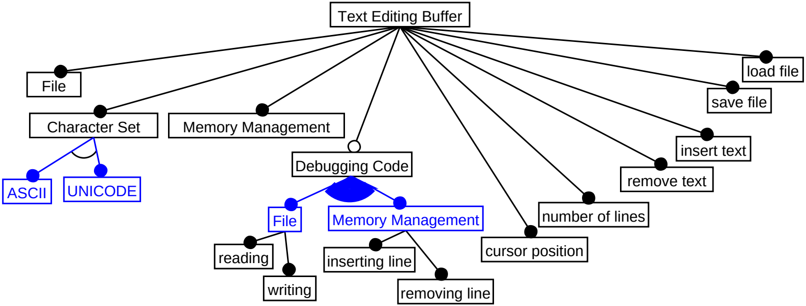
[2] V. Vranić. Reconciling Feature Modeling: A Feature Modeling Metamodel. In M. Weske and P. Liggesmeyer, Eds., *Proc. of 5th Annual International Conference on Object-Oriented and Internet-Based Technologies, Concepts, and Applications for a Networked World (Net.ObjectDays 2004)*, Erfurt, Germany, Sept. 2004. Springer.

Feature Variability (1)



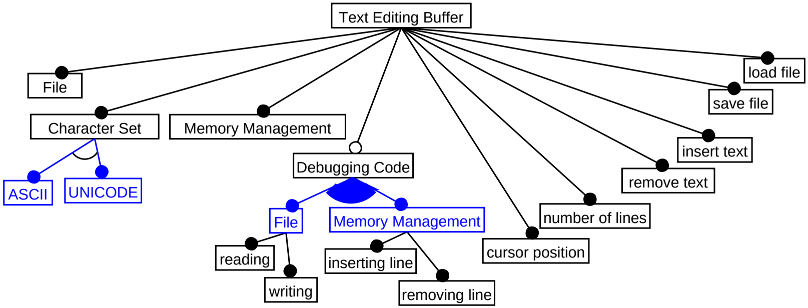
- *Mandatory* features (edges ended by filled circles)
- *Optional* features (edges ended by empty circles)

Feature Variability (2)



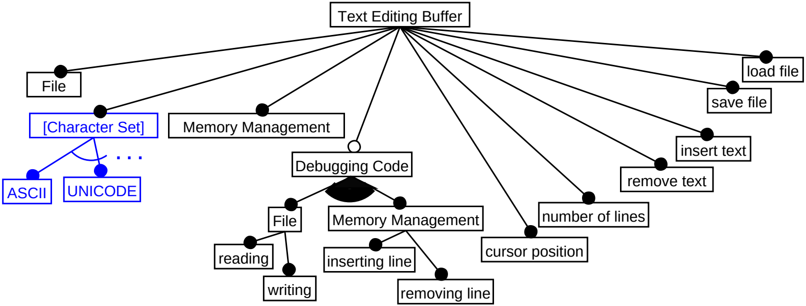
- *Alternative* features (empty arc)
- *Or*-features (filled arc)

Feature Variability (3)



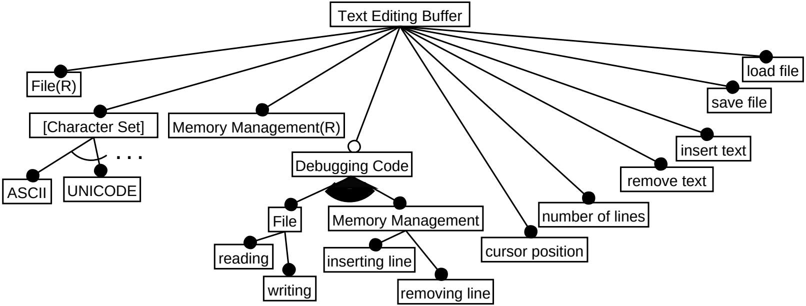
- Arcs modify the meaning of edges
    - Mandatory/Optional alternative features
    - Mandatory/Optional or-features

Feature Variability (4)



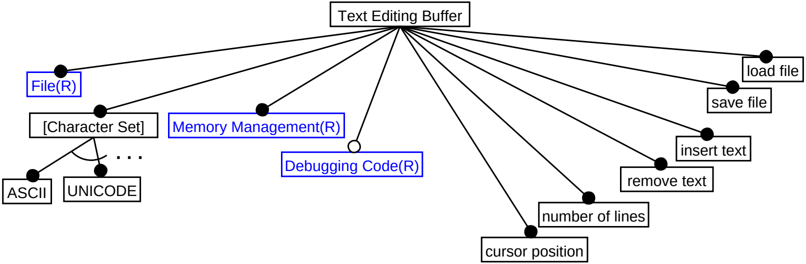
- Open features
  - Further variable subfeatures are expected
  - Denoted by square brackets; ellipsis is sometimes added

Feature Variability (5)



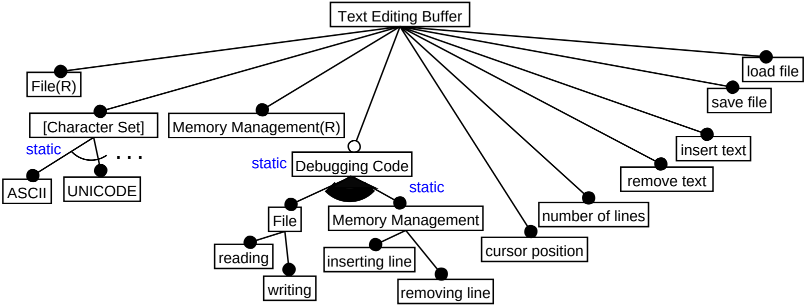
- A feature can be included into a concept instance only if its parent has been included
- Features of all types may appear at any level

Concept References



- Denoted by ® ((R) in diagrams in this presentation)
- May be expanded as needed

Binding time/mode

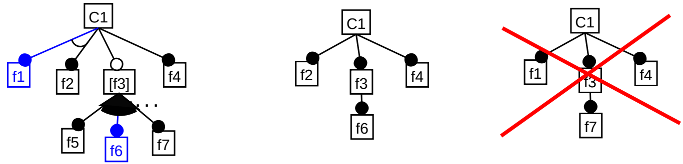


- Binding time/mode
- When/how a feature will be bound
- Common binding times are source code, compile, link, load, and runtime
- Biding mode: static or dynamic

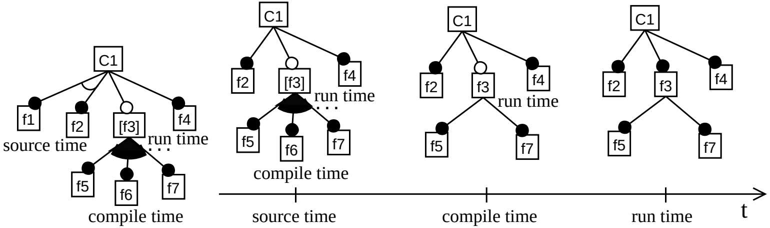
Additional Information in Feature Models

- Information associated with concepts and features
  - Textual information: description, presence rationale, inclusion rationale, note
  - Binding time/mode
- Constraints and default dependency rules
  - An example constraint:

$$f1 \Rightarrow f6$$



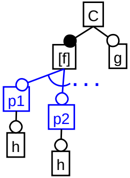
Concept instantiation



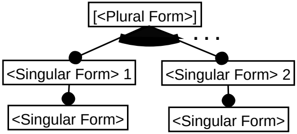
Parameterization in Feature Models

- Parameterized feature and concept names

Constraint: $\forall <i> \in N \; p<i>.h \veebar g$



- Parameterized concepts



Aspects and Variability (1)

- In traditional approaches to implementation, the given feature code may be scattered across several components
- This is especially important for variable features, because they are being bound and unbound according to the choosen configuration
- Lee et al.:[3]
  - Common features implemented as usual
  - Variable features implemented with aspects

[3] Lee et al. Combining Feature-Oriented Analysis and Aspect-Oriented Programming for Product Line Asset Development. In Proc. of 10th International Software Product Line Conference, Aug. 2006. IEEE Cpmputer Society.

Aspects and Variability (2)

- In reality, a more thorough analysis is needed for each feature in order to determine how it should be implemented
- General rules of aspect-oriented approach apply: features that crosscut other features should be implemented in the aspect-oriented way regardless of being variable or not
- Specific issues related to product lines should be considered (with respect to feature interdependencies)
- Binding time should be considered, too

Feature Interaction Problem

- Some features depend on other features
- A feature may require the presence or absence of another feature
- This relationship may be uni- or bidirectional
- Abstract aspects—the way how to separate dependencies
    - Dependencies are implemented as concrete pointcuts in concrete aspects
    - The functionality itself is in an abstract aspect

Multi-Paradigm Design with Feature Modeling

- Multi paradigm design with feature modeling (MPD_{fm})[4] — a method for paradigm selection
- Software development process can be viewed as a mapping of the application (problem) domain to the solution domain
- Software development paradigm then determines how to express application domain concepts in terms of solution domain concepts
- Concepts of the solution domain correspond to programming language mechanisms
- Individual concepts of the solution domain (e.g., class in Java) may be considered as paradigms
- The approach is based on Coplien's multi-paradigm design[5]

[4] Valentino Vranić. Multi-paradigm design with feature modeling. Computer Science and Information Systems Journal (ComSIS). 2(1): 79–102, 2005. http://comsis.fon.bg.ac.yu/ComSIS/Vol2No1/RegularPapers/VVranic.htm

[5] J. O. Coplien. Multi-Paradigm Design for C++. Addison-Wesley, 1998. (J. O. Coplien. Multi-Paradigm Design. PhD thesis, Vrije Universiteit Brussel, 2000. http://users.rcn.com/jcoplien/Mpd/Thesis/Thesis.pdf)

Coplien's Multi-Paradigm Design

Variability tables (from application domain SCVR analysis)

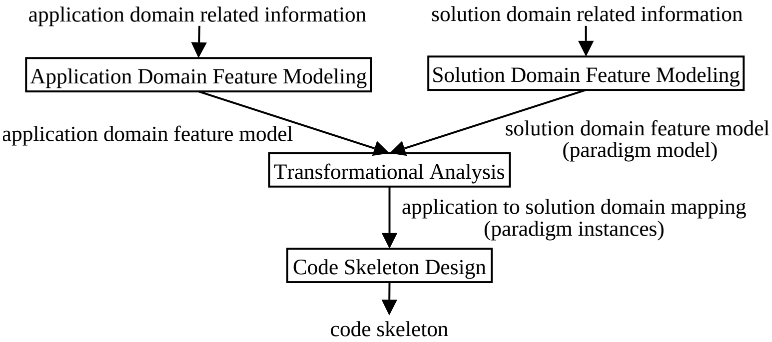
Text Editor Variability Analysis for Commonality domain:
TEXT EDITING BUFFERS (*Commonality: Behavior and Structure*)

Parameters of variation	Meaning	Domain	Binding	Default
Output medium *Structure, Algorithm*	...	Database, RCS file, TTY, UNIX file	Run time	UNIX file

Family table (from solution domain SCVR analysis)

Commonality	Variability	Binding	Instantiation	Language Mechanism
		. . .		
Related operations and some structure (positive variability)		. . .		
	Algorithm (especially multiple), as well as (optional) data structure and state	Compile time	Optional	Inheritance
	Algorithm, as well as (optional) data structure and state	Run time	Optional	Virtual functions

$\mathrm{MPD}_{\mathrm{FM}}$ Activities (repeated)

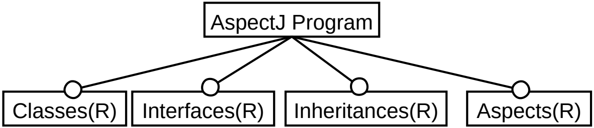


Modeling Paradigms in $\mathrm{MPD}_{\mathrm{FM}}$

- Paradigm identification
  - Directly and indirectly usable paradigms
  - Paradigm hierarchy
- Binding time identification
  - Determining the sequence of binding times available in the solution domain
  - E.g., in AspectJ method body has the runtime binding
- First-level paradigm model
- Modeling individual paradigms

First-Level Paradigm Model

- First-level paradigm model consists of directly usable paradigms
  - Features of the solution concept
  - Introduced as concept references (usually in plural)
  - Their variability and binding time has to be determined
- Example: AspectJ first-level paradigm model



Modeling Individual Paradigms

- Each paradigm is introduced in a separate feature diagram
  - Solution domain concepts
  - May refer one to another
- Auxiliary concepts
  - Concepts that paradigms refer to
  - But they are not considered to be paradigms themselves
- Binding time (variable features)
- Instantiation (e.g., class–objects) is modeled with features

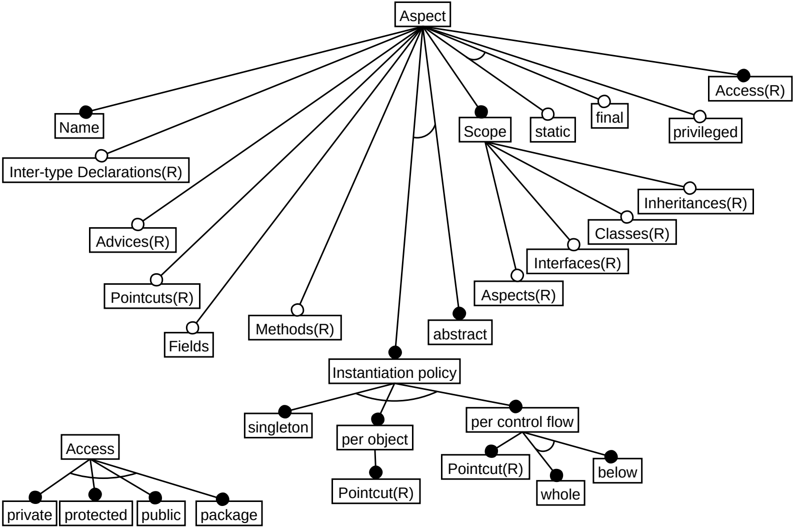
Structures and Relationships

- Structural paradigms correspond to the main constructs (structures) of the programming language
- Relationship paradigms are about relationships among the programming language structures
- In transformational analysis a node in the application domain feature model
  - May correspond to the root of a structural paradigm
  - But can't correspond to the root of a relationship paradigm

AspectJ Aspect-Oriented Paradigms

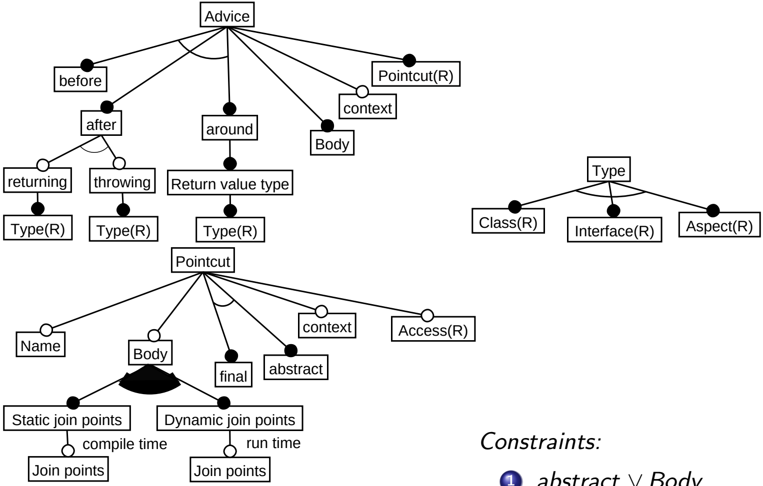
- Aspect paradigm—stuctural paradigm (modularization)
- A container for further aspect-oriented paradigms: advice, pointcut, and inter-type declaration
- These paradigms are structural paradigms (corresponds to their task—to capture crosscutting concerns)

Aspect



Constraint: abstract $\veebar$ *final*

Advice and Pointcut



Constraints:

1. $abstract \vee Body$
2. $Access \Rightarrow Name$

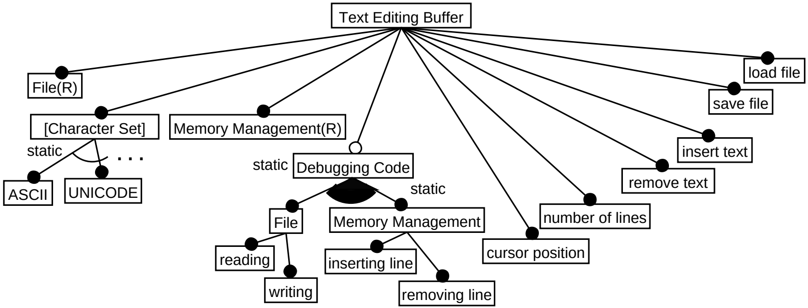
Transformational Analysis in $\mathrm{MPD}_{\mathrm{FM}}$

- Bottom-up instantiation of paradigms over application domain concepts at source time
- Application domain concepts are considered one by one
  1. The corresponding structural paradigm is determined
  2. The corresponding relationship paradigms for each relationship in it are determined

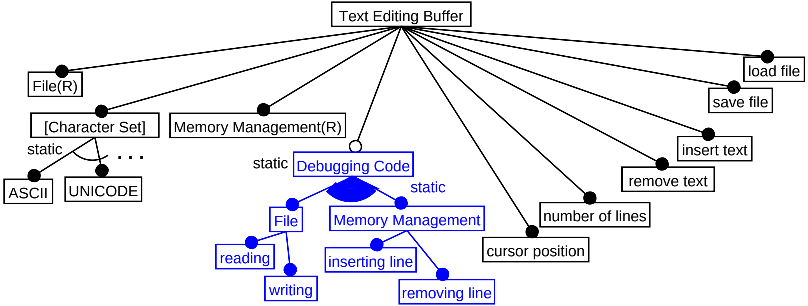
Paradigm Instantiation in $\mathrm{MPD}_{\mathrm{FM}}$

- Paradigm instantiation in $\mathrm{MPD}_{\mathrm{FM}}$ is actually concept instantiation
  - Understood as concept specialization
  - Concept instances are represented by feature diagrams
  - Binding time is being taken into account
- Bottom-up instantiation
- Inclusion of paradigm nodes is determined by the mapping of the nodes of application domain concepts
  - Conceptual correspondence
  - Binding time correspondence

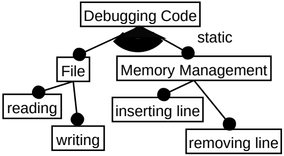
Transformational Analysis Example (1)



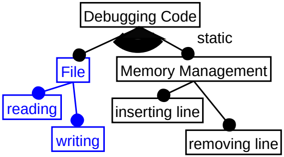
Transformational Analysis Example (2)



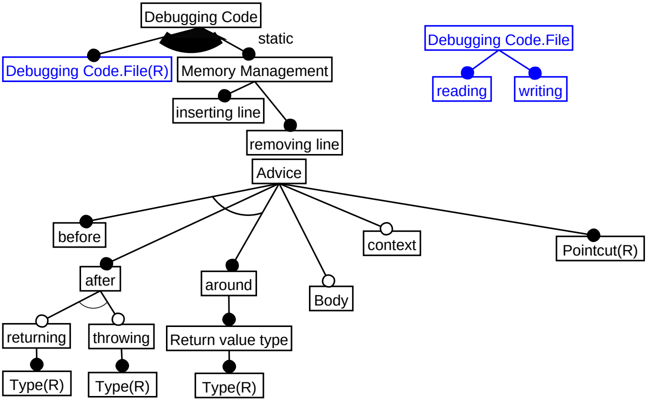
Transformational Analysis Example (3)



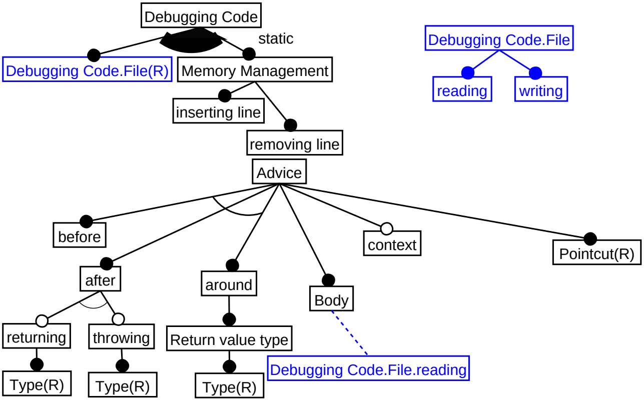
Transformational Analysis Example (4)



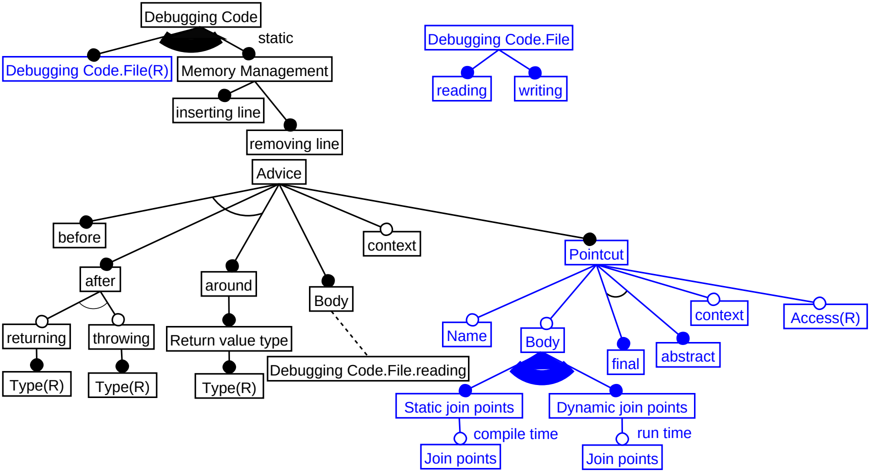
Transformational Analysis Example (5)



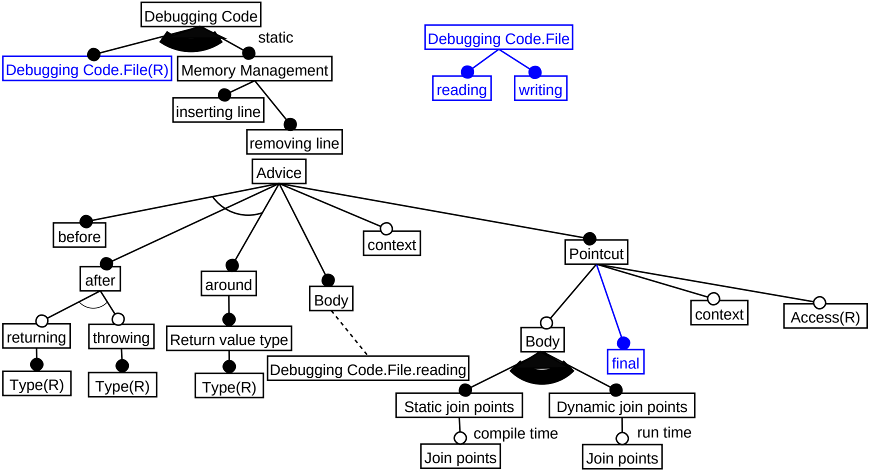
Transformational Analysis Example (6)



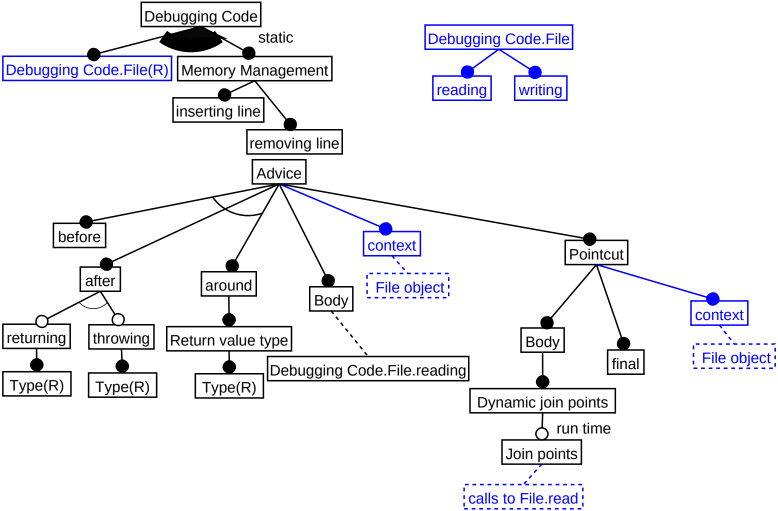
Transformational Analysis Example (7)



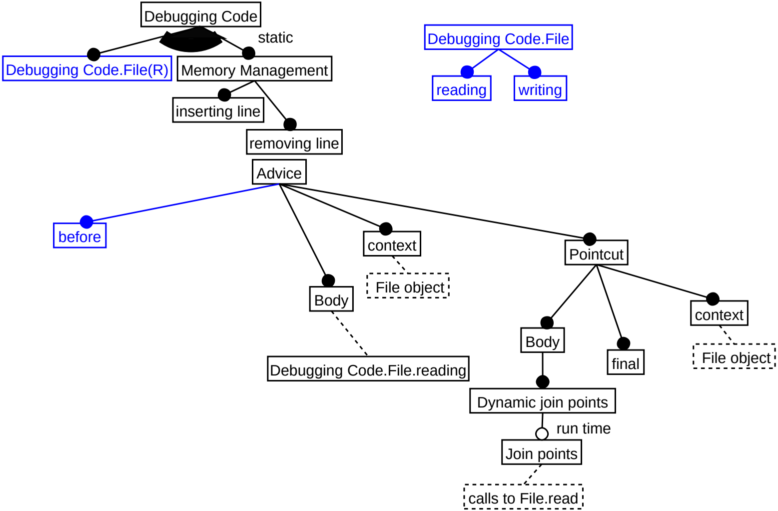
Transformational Analysis Example (8)



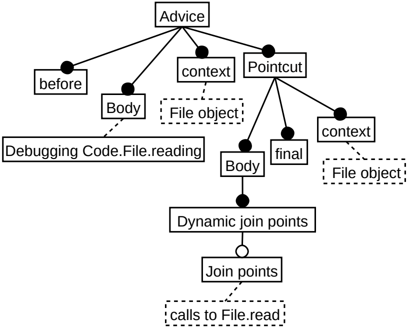
Transformational Analysis Example (9)



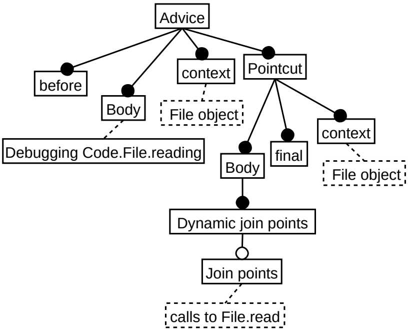
Transformational Analysis Example (10)



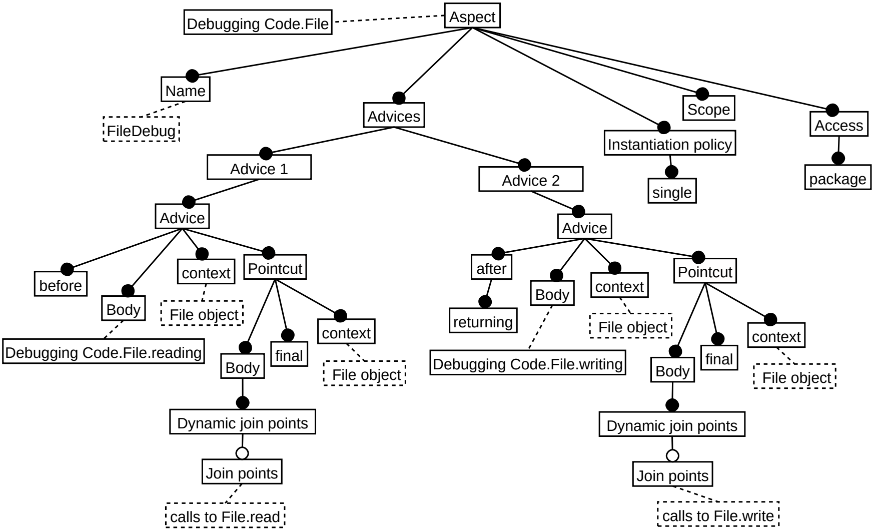
Transformational Analysis Example (11)



Transformational Analysis Example (12)



Transformational Analysis Example (13)



Code Skeleton Design

- Code is designed by traversing the trees of paradigm instances
- Structural paradigm instances are considered first
- Example: the aspect of the file debugging code

```
aspect FileDC {
  before(File f): target(f) && call(* File.read(..)) {
      . . .
  }

  after(File f): target(f) && call(* File.write(..)) {
      . . .
  }
}
```

Summary

- MPD$_{\mathrm{FM}}$: a method of paradigm selection based on feature modeling
- Paradigms are viewed as solution domain concepts
- The key activity: transformational analysis performed as a bottom-up paradigm instantiations over application domain concepts
- Transformational analysis can be applied to all application domain concepts, but can also be restricted to critical ones
- The AspectJ paradigm model
- Further research:
  - Use of MPD$_{\mathrm{FM}}$ for early aspect identification
  - Use of feature modeling adapted to MPD$_{\mathrm{FM}}$ to deal with the interaction of aspect-oriented change realizations