11. Bridging the Technical Spaces Grammarware and EMOFware using EMFText

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1) What is a DSL?
2) How to build a DSL
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3) Advanced features of EMFText
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    2) Reference resolving
    3) Syntax modules (Import and Reuse)
    4) Interpretation vs. Compilation
4) Other DSL examples in the Zoo
5) Appendix: Integrating DSLs and GPLs

Obligatory LIterature

- Florian Heidenreich, Jendrik Johannes, Sven Karol, Mirko Seifert, and Christian Wende. Model-based language engineering with EMFText. In Ralf Lämmel, João Saraiva, and Joost Visser, editors, GTTSE, volume 7680 of Lecture Notes in Computer Science, pages 322-3411. Springer, 2011.

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Recommended Literature

EMFText is on gitlab, by our start-up, DevBoost
www.devboost.de
https://github.com/DevBoost/

- Many tools under https://github.com/DevBoost/
- Florian Heidenreich, Jendrik Johannes, Sven Karol, Mirko Seifert and Christian Wende. Derivation and Refinement of Textual Syntax for Models. In Proc. of the 5th European Conference on Model-Driven Architecture Foundations and Applications (ECMDA-FA 2009).
- Mirko Seifert and Christian Werner. Specification of Triple Graph Grammar Rules using Textual Concrete Syntax. 7th International Fujaba Days, 2009
- Florian Heidenreich, Jendrik Johannes, Mirko Seifert and Christian Wende. Construct to Reconstruct - Reverse Engineering Java Code with JaMoPP. In Proc. of the International Workshop on Reverse Engineering Models from Software Artifacts (R.E.M.'09).
- Florian Heidenreich, Jendrik Johannes, Mirko Seifert and Christian Wende. Closing the Gap between Modelling and Java Tool demonstration at the 2nd International Conference on Software Language Engineering (SLE'09).
- Florian Heidenreich, Jendrik Johannes, Mirko Seifert, Christian Wende and Marcel Böhme. Generating Safe Template Languages. In Proc. of the 8th International Conference on Generative Programming and Component Engineering (GPCE 2009).
- Christian Wende and Florian Heidenreich. A Model-based Product-Line for Scalable Ontology Languages. In Proc. of the 1st International Workshop on Model-Driven Product-Line Engineering (MDPLE 2009) collocated with ECMDA-FA 2009. Enschede, The Netherlands, June 2009.
- Mirko Seifert and Roland Samlaus. Static Source Code Analysis using OCL. In Proc. of OCL Workshop 2008 at MODELS 2008
- Jakob Henriksson, Florian Heidenreich, Jendrik Johannes, Steffen Zschaler and Uwe Aßmann. Extending Grammars and Metamodels for Reuse -- The Reuseware Approach. IET Software Journal 2008.

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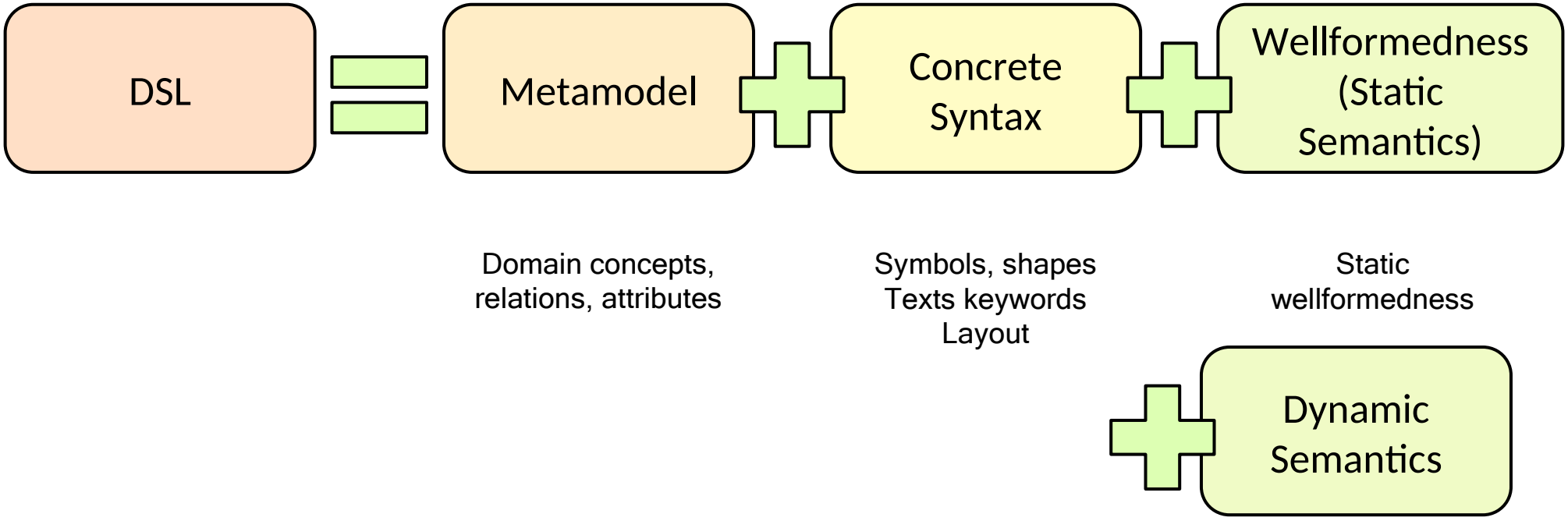
11.1 What is a Domain-Specific Language (DSL)?

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

What's in a Domain-Specific Language (DSL)?

- The core of a DSL is a metamodel on M2 derived from the lifted core metamodel (e.g., EMOF)



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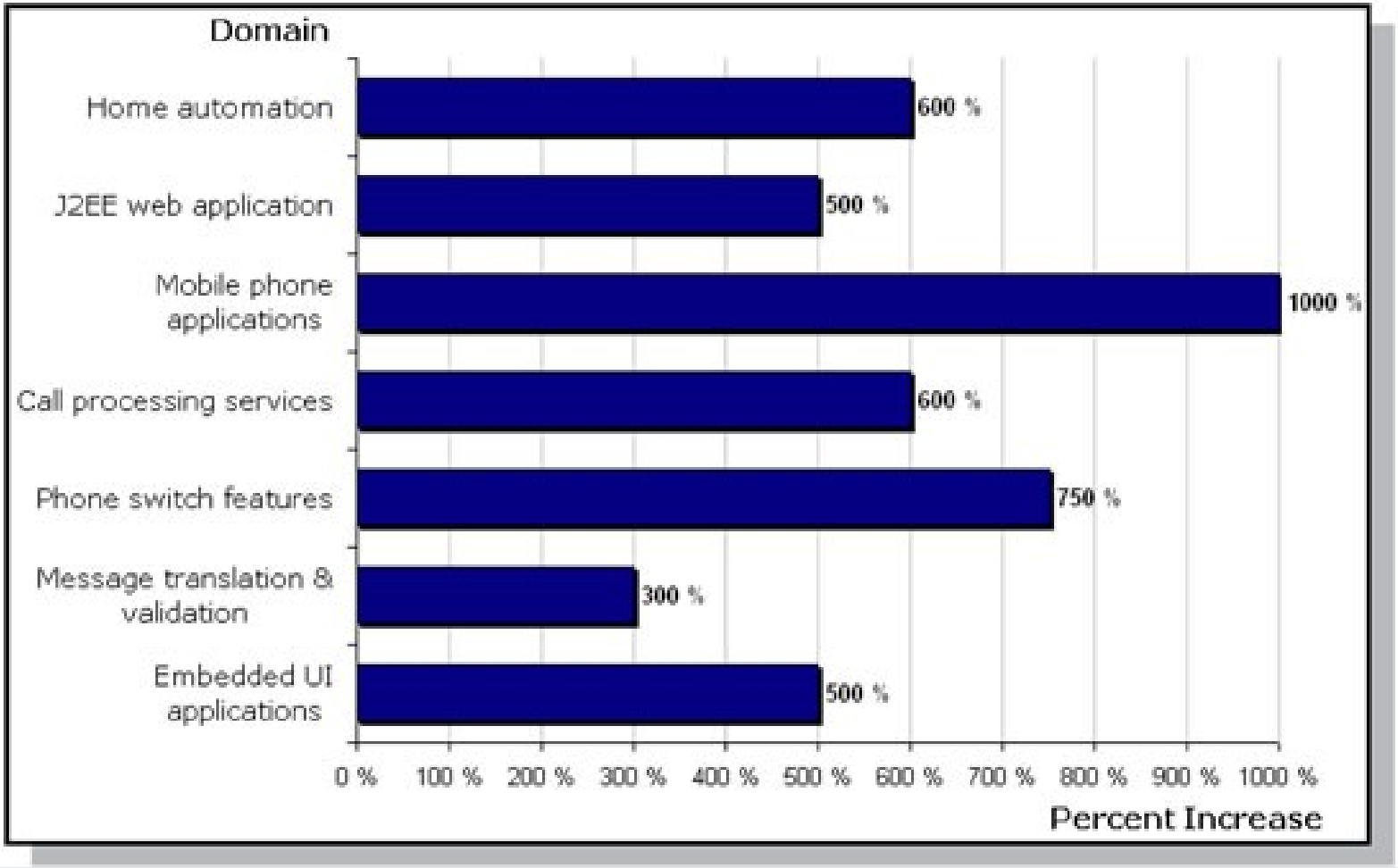
Productivity Gains with DSL



Juha-Pekka Tolvanen. Domain-Specific Modeling for Full Code Generation. January 2010. Vol. 12, Number 4. http://journal.thedacs.com/issue/52/144

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Motivation – Why Metamodel-Based DSLs?

Pros

+ Enhance productivity, reliability, maintainability and portability
+ Co-evolution is simpler, because metaprograms may influence M1
+ Use the concepts and idioms of a domain in a metamodel
    - Domain experts can understand, validate and modify DSL programs (good for communication between domain experts and programmers)
    - Higher level of abstraction
    - Expressiveness in a domain
+ Concise and self-documenting
+ Embody domain knowledge, enabling the conservation and reuse of this knowledge

But:

- Costs of design, implementation and maintenance
- Costs of education for users
- Limited availability of DSLs
- Evolution is not easy to organize

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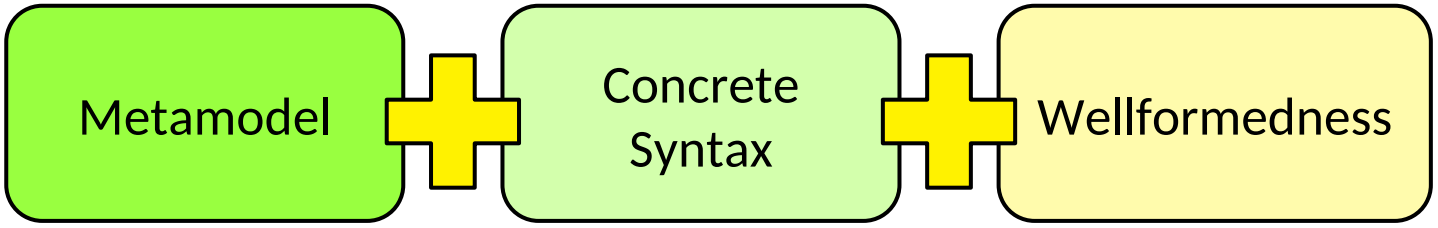
What is a Textual Domain-Specific Language (DSL)?

- The **EMFText tool suite** relates a concrete syntax specification (grammar in EBNF) to a EMOF/Ecore-based metamodel.
- From this language mapping, printers, parsers and editors for a DSL can be generated



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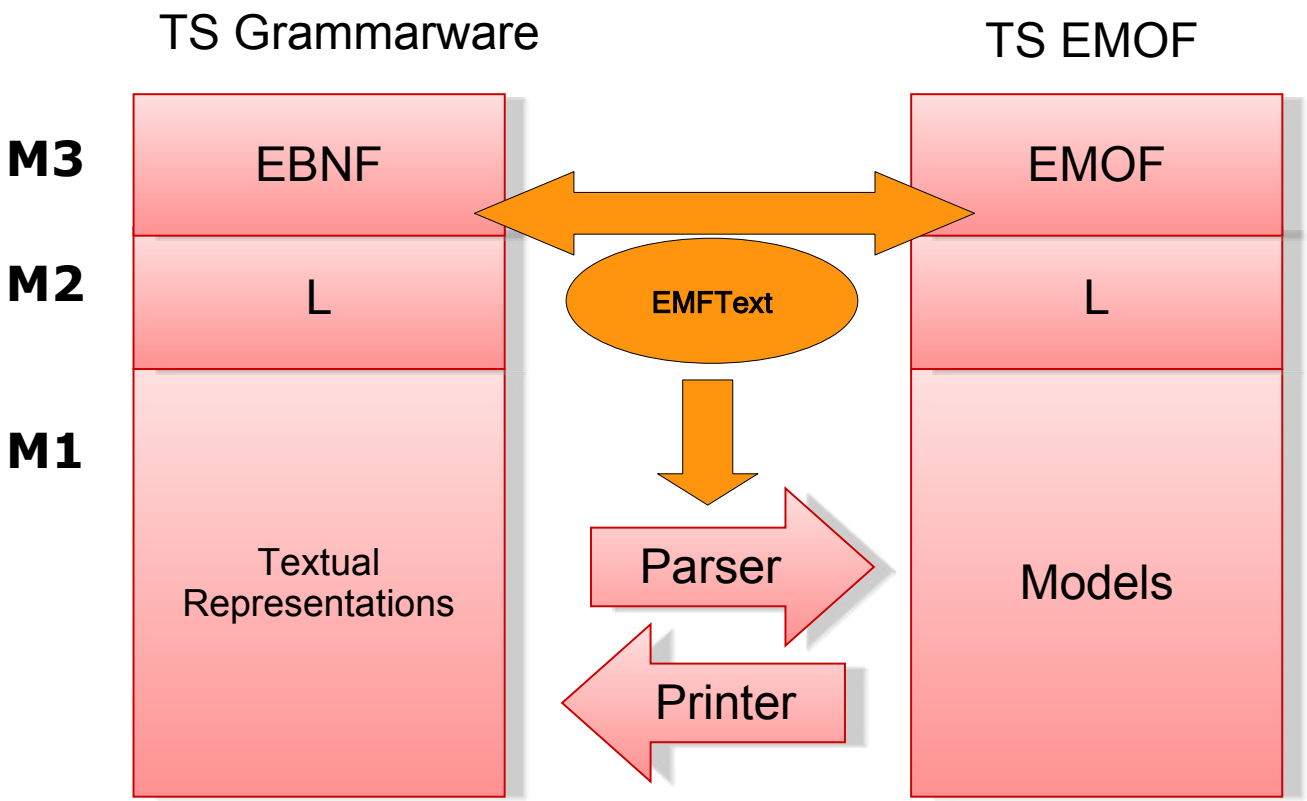
Textual DSL rely on a Transformation Bridge between the Technical Spaces EMOF and Grammarware

- The **EMFText tool suite** relates a concrete syntax specification (grammar in EBNF) to a EMOF/Ecore-based metamodel.
- From this language mapping, printers (unparsers), parsers and editors are generated
- EMFText can be used to produce normative concrete syntax for exchange formats



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EMFText Motivation – Why Textual syntax?

Why use textual syntax for models?

- Readability
- Diff/Merge/Version Control
- Evolution
- Tool autonomy
- Quick model instantiation

Why create models from text?

- Tool reuse (e.g., to perform transformations (ATL) or analysis (OCL))
- Know-how reuse
- Explicit representation of text document structure
- Tracing software artifacts
- Graphs instead of strings

Be aware: exchange syntax is like a textual DSL

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EMFText Philosophy and Goals

Design principles:

- Convention over Configuration
- Provide defaults wherever possible
- Allow customization for all parts of a syntax

Syntax definition should be

- Simple and easy for small DSLs
- Yet powerful for complex languages

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EMFText Features

- **Generation Features**
  - Generation of independent code
  - Generation of Default Syntax Grammar (via default language mapping)
  - Customizable Code Generation
- **Specification Features**
  - Modular Specification
  - Default Reference Resolving
  - Comprehensive Syntax Analysis
- **Editor Features**
  - Code Completion, Customizable Syntax and Occurence Highlighting, Code Folding, Error Marking, Hyperlinks, Text Hovers, Outline View, ...
- **Other Highlights**
  - ANT Support, Post Processors, Builder, Interpreter and Debugger Stubs, Quick Fixes
  - Full Java support (JaMOPP)

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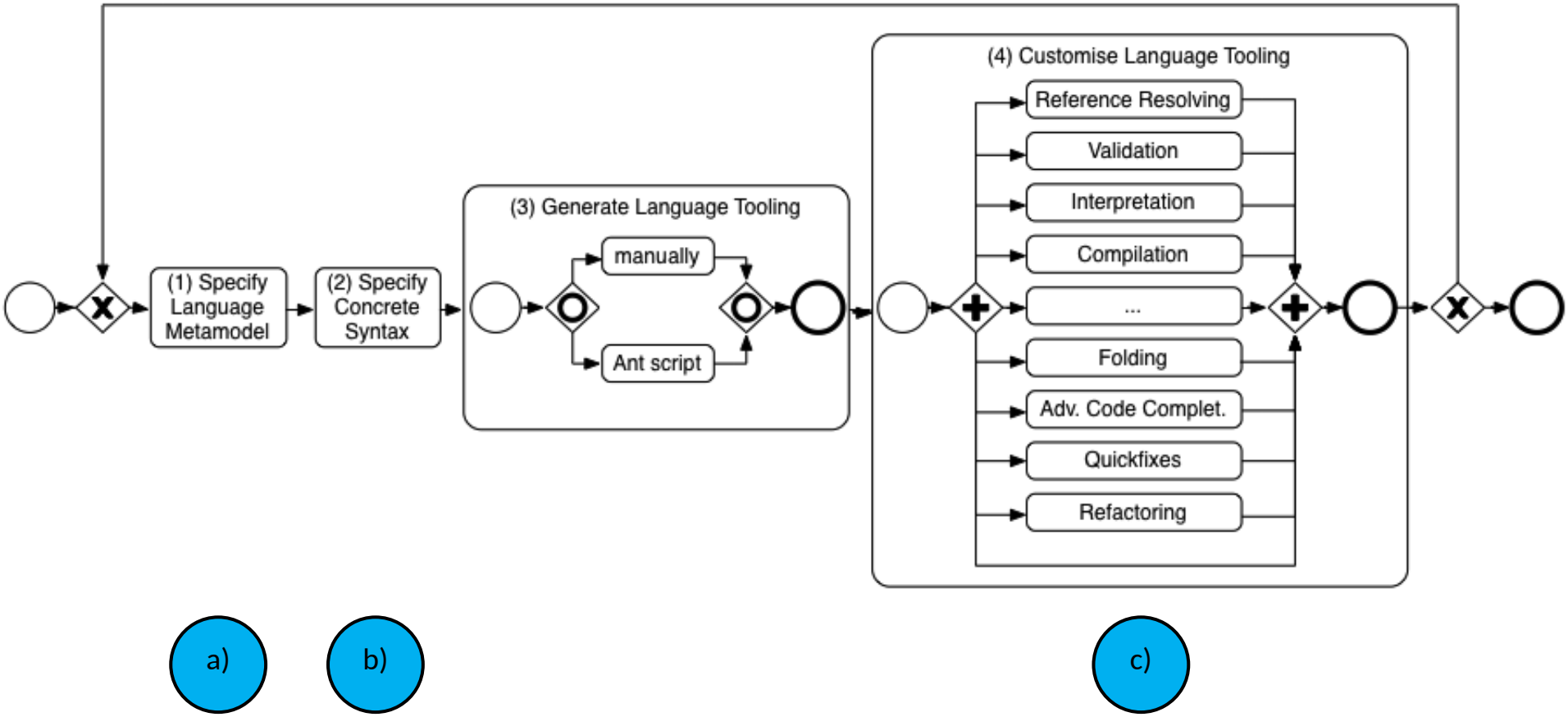
11.2 How to Build a DSL with EMFText

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

EMFText Language Development Process



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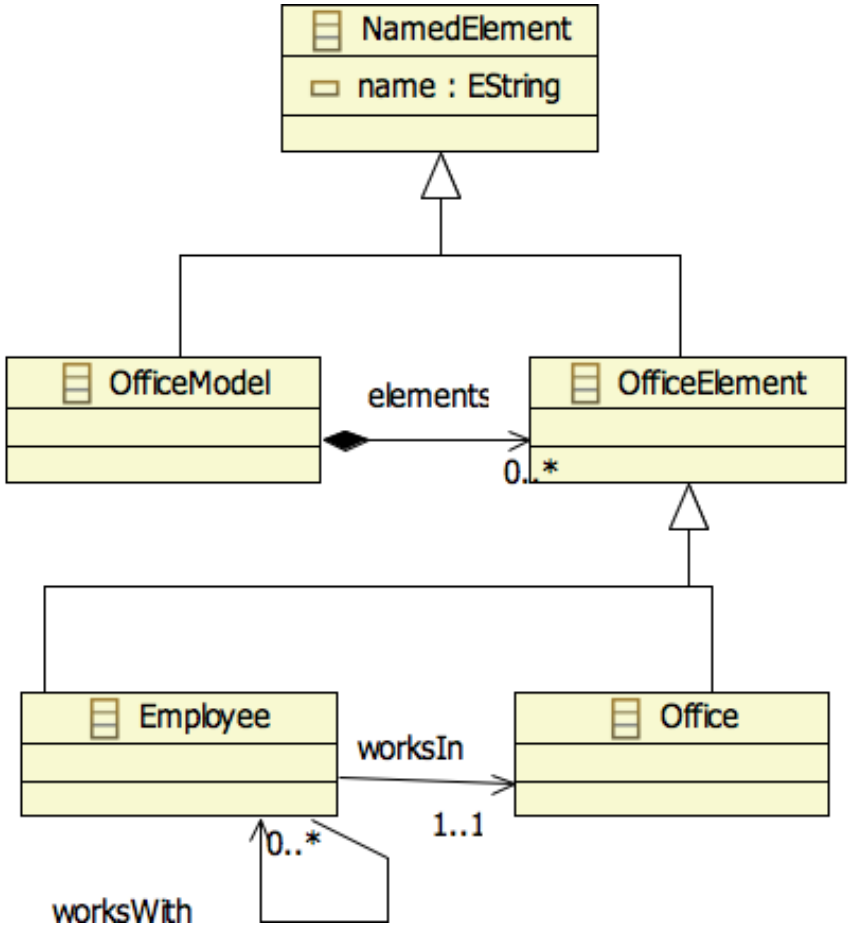
How to build a DSL – Metamodel

a)



Creating a new Metamodel:

- Define concepts, relations and properties in an Ecore model
- Existing Metamodels can be imported (e.g., UML, Ecore, …)

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How to build a DSL – Metamodel

a)

Repetition: Metamodel elements (EMF concepts):

- Classes
- Data Types
- Enumerations

- Attributes
- References (Containment, Non-containment)
- Cardinalities

- Inheritance

- The Office DSL is a *Material* metamodel, because offices are treated as data

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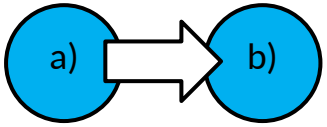
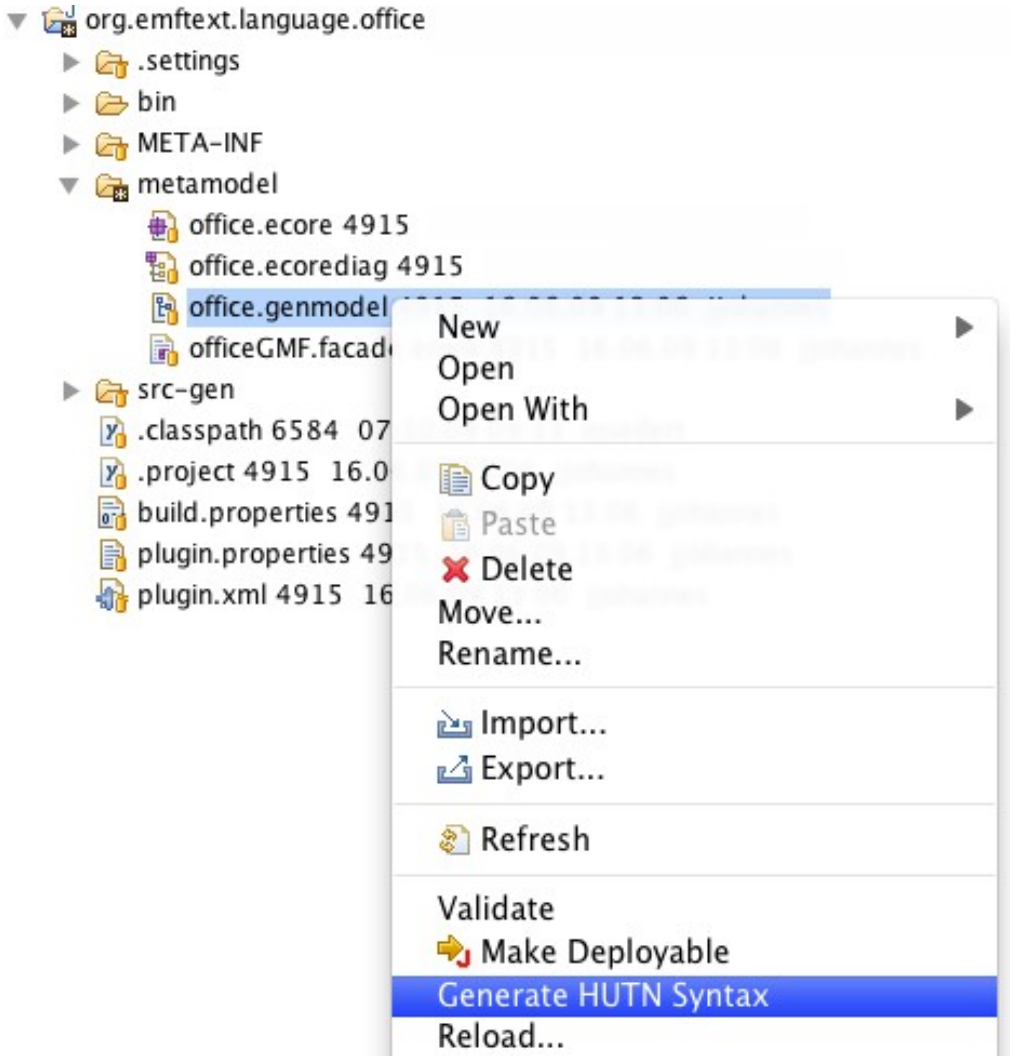
Generate Initial Syntax (Human Usable Text Notation)





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Initial HUTN Syntax – Generated Grammar

b)

- All metaclasses of the EMOF metamodel become nonterminals in the text grammar

office.cs

```
SYNTAXDEF office
FOR <http://emftext.org/office>
START OfficeModel

TOKENS{
    DEFINE COMMENT$'//'(~('\n'|'\r'|'\uffff'))*$;
    DEFINE INTEGER$('-')?('1'..'9')('0'..'9')*|'0'$;
    DEFINE FLOAT$('-')?(('1'..'9') ('0'..'9')* | '0') '.' ('0'..'9')+ $;
}

TOKENSTYLES{
    "OfficeModel" COLOR #7F0055, BOLD;
    "name" COLOR #7F0055, BOLD;
    "elements" COLOR #7F0055, BOLD;
    "Employee" COLOR #7F0055, BOLD;
    "worksIn" COLOR #7F0055, BOLD;
    "worksWith" COLOR #7F0055, BOLD;
    "Office" COLOR #7F0055, BOLD;
}

RULES{

    OfficeModel::= "OfficeModel"  "{" ( "name"  ":" name['"','"'] | "elements"  ":" elements  )* "}"  ;

    Employee::= "Employee"  "{" ( "name"  ":" name['"','"'] | "worksIn"  ":" worksIn[]| "worksWith"  ":" worksWith[] )* "}"  ;

    Office::= "Office"  "{" ( "name"  ":" name['"','"']  )* "}"  ;

}
```

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Initial, Generated HUTN Syntax – Example Document

b)

st.office

```
OfficeModel {
    name : "SoftwareTechnology"

    elements :
        Office {
            name : "INF2080"
        }

    elements :
        Office {
            name : "INF2084"
        }

    elements :
        Employee {
            name : "Florian"
            worksIn : INF2080
            worksWith : Jendrik
        }

    elements :
        Employee {
            name : "Jendrik"
            worksIn : INF2084
            worksWith : Florian
        }
}
```

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Syntax Refinement:
User Modifies Grammar to Remove Brackets


```
//*****************************************************************************
// Copyright (c) 2006-2010
// Software Technology Group, Dresden University of Technology
//
// All rights reserved. This program and the accompanying materials
// are made available under the terms of the Eclipse Public License v1.0
// which accompanies this distribution, and is available at
// http://www.eclipse.org/legal/epl-v10.html
//
// Contributors:
//   Software Technology Group - TU Dresden, Germany
//      - initial API and implementation
// MODIFIED, SIMPLIFIED GRAMMAR
// ****************************************************************************/
SYNTAXDEF office
FOR <http://emftext.org/office>
START OfficeModel
OPTIONS {
        licenceHeader ="../../org.dropsbox/licence.txt";
        generateCodeFromGeneratorModel = "true";
        disableLaunchSupport = "true";
        disableDebugSupport = "true";
}
RULES {
        OfficeModel ::= "officemodel" name[]
                                    "{" elements* "}" ;

        Office ::= "office" name[];

        Employee ::= "employee" name[]
                                "works" "in" worksIn[]
                                "works" "with"
                                worksWith[] ("," worksWith[])* ;
}
```

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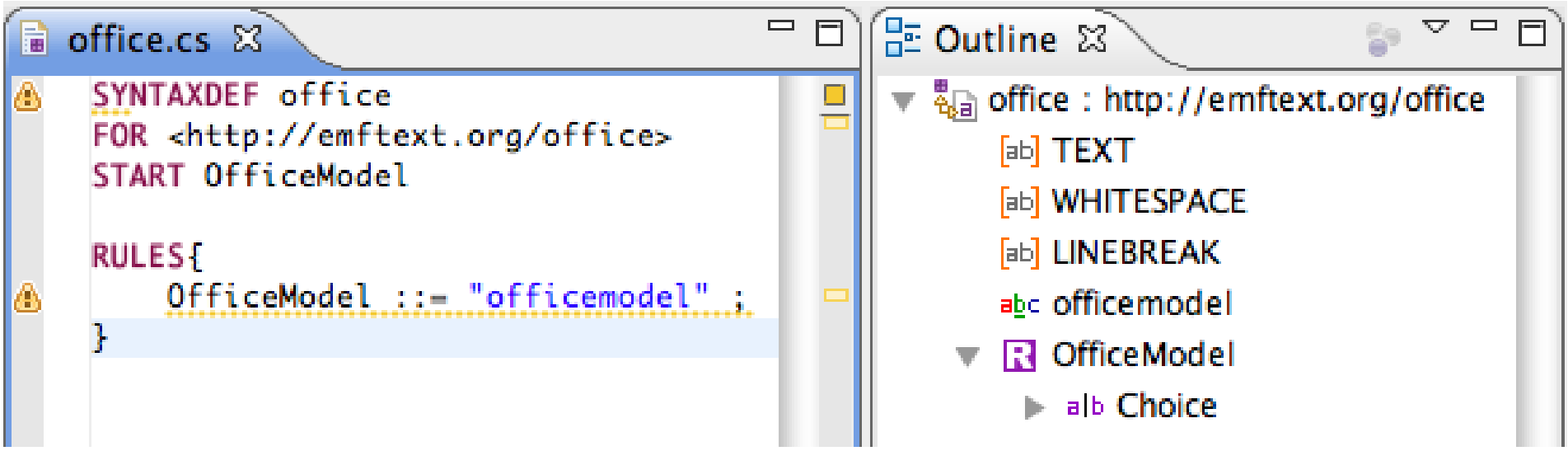
Syntax Refinement – The Concrete Syntax Language CS

b)

Structure of a .cs file:

- Header
  - File extension
  - Metamodel namespace URI, *location*
  - Start element(s)
  - *Imports (Metamodels, other syntax definitions)*
- *Options*
- *Token Definitions*
- Syntax Rules



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Syntax Refinement – Syntax Rules in EBNF

b)

- The structure of CS is defined in EBNF (Extended Backus-Naur Form), the dominating metalanguage of the Grammarware technical space

- **Definition elements in EBNF rules:**
  - Static strings (keywords) "public"
  - Choices a|b
  - Multiplicities +,*
  - Compounds (ab)
  - Terminals a[] (Non-containment references, attributes)
  - Non-terminals a (Containment references)

- **Language mapping:** One syntax rule per metaclass (concept mapping):
  - This defines the *language mapping* between EBNF and EMF metaclasses
  - Syntax: `MetaClassName ::= Syntax Definition ;`
- All concept mappings define a *language mapping*

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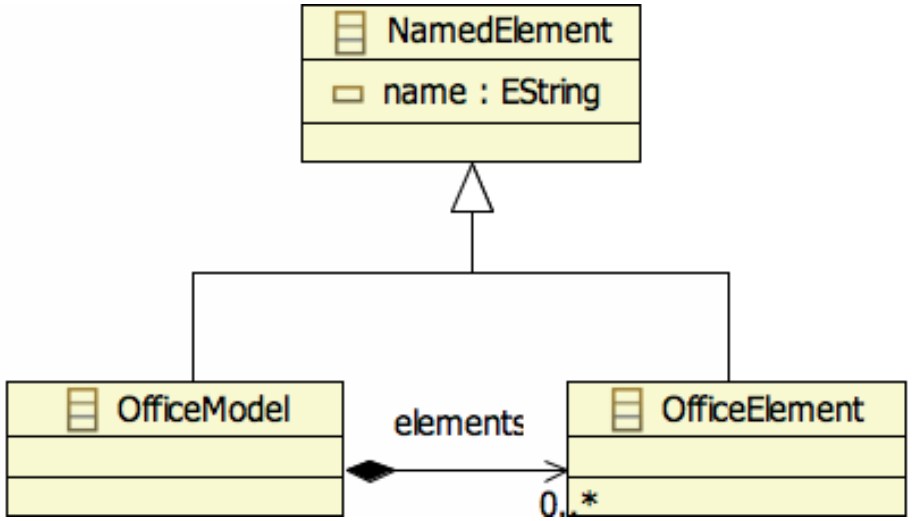
Customizing Syntax Rules - Examples

b)

// EMOF Metamodel




```
// Grammar Rule
OfficeModel ::= "officemodel" name[]
                "{" elements* "}" ;
```

```
// Textual model
officemodel SoftwareTechnology {
  ...
}
```

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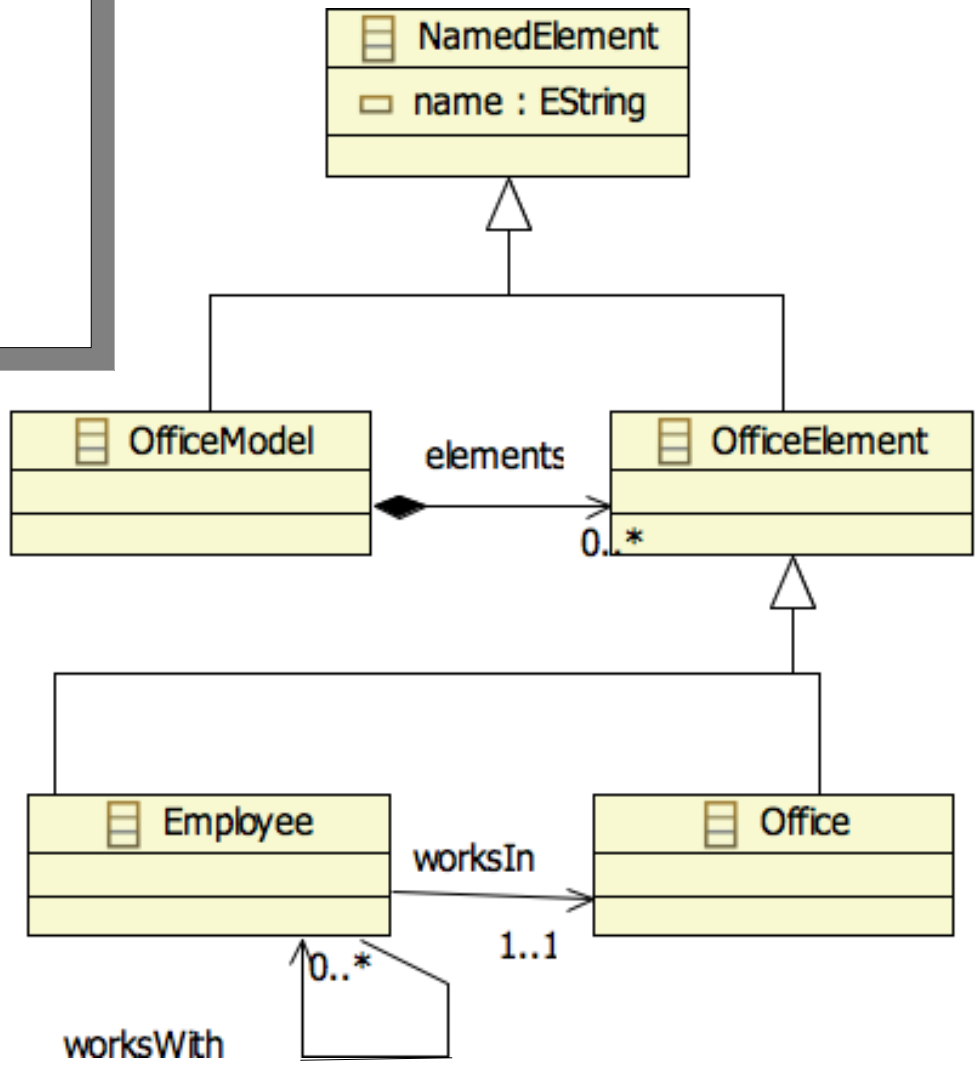
Customizing Syntax Rules - Examples


```
RULES {
    OfficeModel ::= "officemodel" name[]"{" elements* "}" ;

    Office ::= "office" name[];

    Employee ::= "employee" name[]
                    "works" "in" worksIn[]
                    "works" "with"
                       worksWith[] ("," worksWith[])* ;
}
```

```
// Text
officemodel SoftwareTechnology {
  office INF2080
  employee Florian
      works in INF2018
}
```

b)

// EMOF Metamodel



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Grammar of Complete Customized Syntax

b)

office.cs

```
SYNTAXDEF office
FOR <http://emftext.org/office>
START OfficeModel

OPTIONS {
    generateCodeFromGeneratorModel = "true";
}

RULES {
    OfficeModel ::= "officemodel" name[]
                    "{" elements* "}" ;

    Office ::= "office" name[];

    Employee ::= "employee" name[]
                 "works" "in" worksIn[]
                 "works" "with"
                 worksWith[] ("," worksWith[])* ;
}
```

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DSM: Generic Syntax vs. Custom Syntax

b)

st.office

```
OfficeModel {
    name : "SoftwareTechnology"

    elements :
        Office {
            name : "INF2080"
        }

    elements :
        Office {
            name : "INF2084"
        }

    elements :
        Employee {
            name : "Florian"
            worksIn : INF2080
            worksWith : Jendrik
        }

    elements :
        Employee {
            name : "Jendrik"
            worksIn : INF2084
            worksWith : Florian
        }
}
```

st.office

```
officemodel SoftwareTechnology {

    office INF2080

    office INF2084

    employee Florian
        works in INF2080
        works with Jendrik

    employee Jendrik
        works in INF2084
        works with Florian
}
```

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11.3. Advanced Features of EMFText

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

Advanced Features – Attribute Mapping

c)

- Putting strings into EString attributes is easy
- How about EInt, EBoolean, EFloat, ..., custom data types?
- Solution A: Default mapping: The generated classes use the conversion methods provided by Java (java.lang.Integer, Float etc.)
- Solution B: Customize the mapping using a token resolver

```
// resolver interface looks up a lexem in the context
// example implementation for TRUE == yes
public void resolve(String lexem,
        EStructuralFeature feature,
        ITokenResolveResult result) {
     if ("yes".equals(lexem)) result.setResolvedToken(Boolean.TRUE);
     else result.setResolvedToken(Boolean.FALSE);
}
public String deResolve(Object value,
      EStructuralFeature feature,
      EObject container) {
   if (value == Boolean.TRUE) return "yes"; else return "no";
}
```

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Advanced Features – Resolving Cross References

c)

Well, quite similar to attribute mappings:

- **Solution A**: Default resolvingSearches for matching elements that have an ID attribute, a name attribute or a single attribute of type EString and picks the first
  - (Works well for simple DSLs without scoping rules)

- **Solution B:** Custom resolvingChange the generated resolver class (implements IReferenceResolver<ContainerType, ReferenceType>)
  - For examples see the resolvers for the Java language

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Advanced Features – Syntax Modules for Language Composition

c)

java_templates.cs

```
SYNTAXDEF java_template
FOR <http://www.emftext.org/language/java_templates>
START JavaTemplate

IMPORTS {
    java : <http://www.emftext.org/java> <../../org.emftext.language.java/metamodel/java.genmodel>
        WITH SYNTAX java <../../org.emftext.language.java/metamodel/java.cs>
}

OPTIONS {
    usePredefinedTokens = "false";
    overrideManifest = "false";
}
```

- Import Metamodels optionally with syntax
- Extend, Combine, Compose existing DSLs
- Create embedded DSLs (e.g., for Java)
- Create a template language from your DSL
- …
- Attention: new URL: https://github.com/DevBoost/EMFText

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Pitfalls of Language Composition (with EMFText)

Syntax and model extensions can be non-trivial

In EMFText problems may be caused by

- Unexpected inclusions between token definitions
- Intersections between token definitions (partial overlaps)
- Problems with the underlying parser generator, e.g. left-recursion or extensive backtracking
- Ambiguous grammars (may require non monotonic changes to the grammar and the metamodels)
- Interference between reference resolvers
- Different language semantics

Detected by EMFText

Avoided by extensive use of keywords

Alternative parsing technologies: Scannerless Parsing, Context-Aware Scanning, SDF/SGLR, MPS, Packrat Parsing, Parsing Expression Grammars ….

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The EMFText Syntax Zoo (>90 residents)

- Ecore, KM3 (Kernel Meta Metamodel)
- Quick UML, UML Statemachines
- Java 5 (complete: JaMOPP), C# (in progress)

- Feature Models
- Regular Expressions
- OWL2 Manchester Syntax

- Java Behavior4UML
- DOT (Graphviz language)

…and lots of example DSLs

https://github.com/DevBoost/EMFText-Zoo

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Conclusion

- Few concepts to learn before using EMFText
- Creating textual syntax for new languages is easy, for existing ones it is harder, but possible (we did Java)
- Rich tooling can be generated from a syntax definition
- Textual and graphical syntax can complement each other (e.g., to support version control)
- Semantics (Interpretation/Compilation) must be defined manually – At most it can be reused

Language is the blood of the soul into which thoughts run
and out of which they grow.

(Oliver Wendell Holmes)

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11.4 Use EMFText for Embedded DSL

- Def.: An ***embedded DSL*** is a DSL extending a general-purpose language (GPL)

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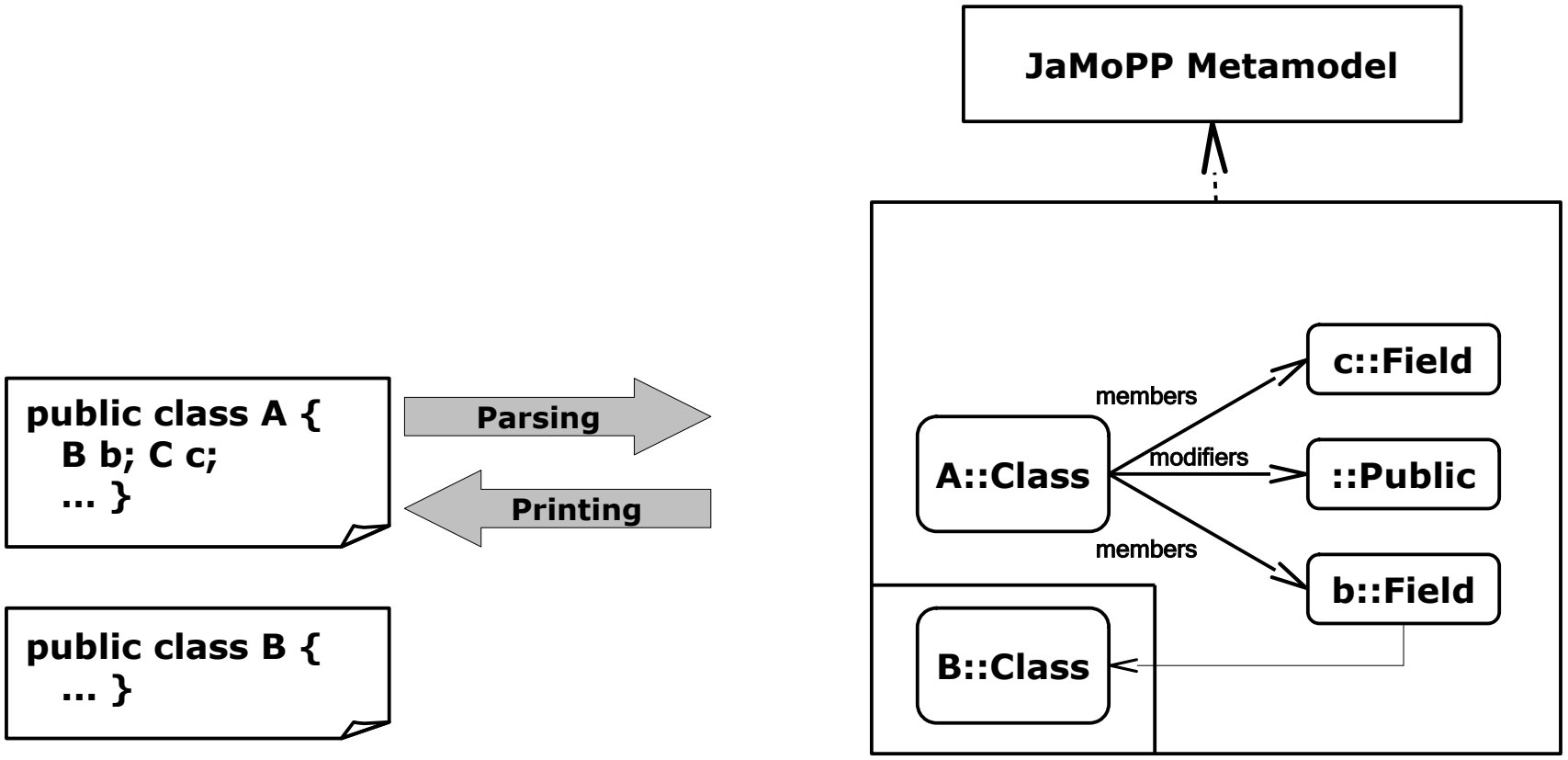
JaMoPP: Lifting Java to DSLs

https://github.com/DevBoost/JaMoPP

- Ingredients:
  - Ecore Metamodel for Java 5 (153 concrete, 80 abstract classes)
  - EMFText .cs definition for each concrete class



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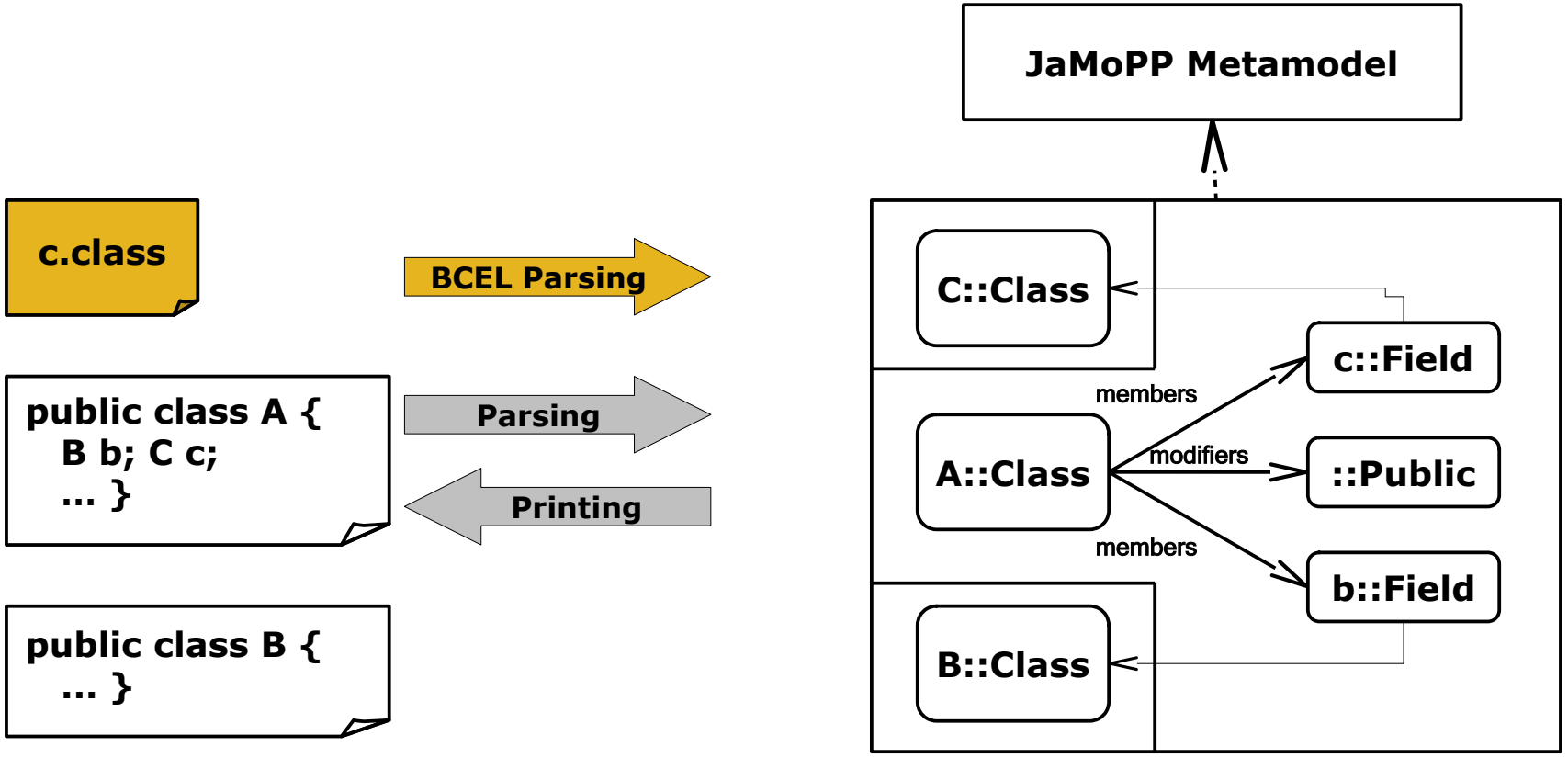
JaMoPP: Lifting Java to DSLs

- Ingredients:
  - Ecore Metamodel for Java 5 (153 concrete, 80 abstract classes)
  - EMFText .cs definition for each concrete class
  - BCEL Bytecode-Parser – to handle third-party libraries



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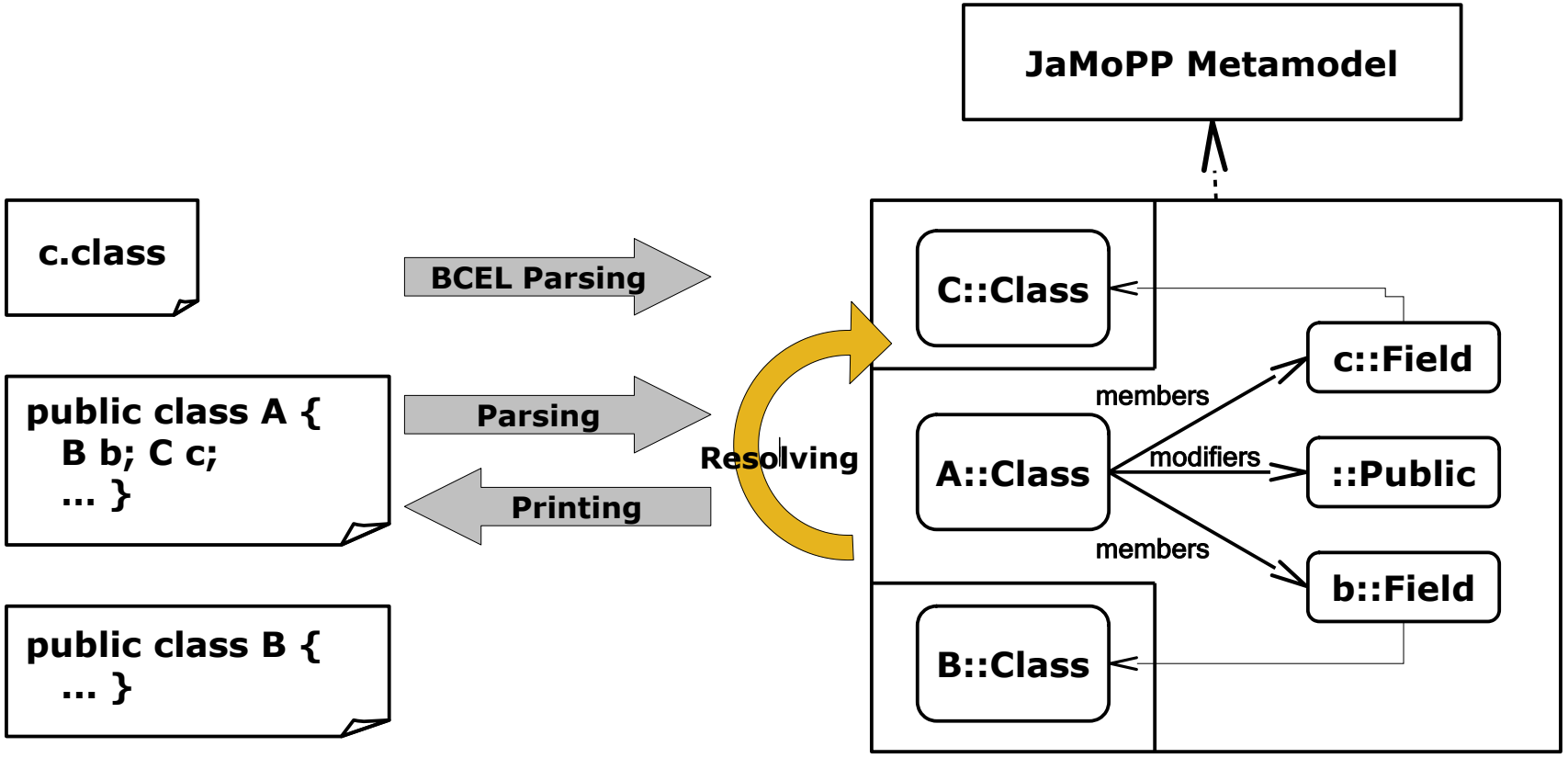
JaMoPP: Lifting Java to DSLs

- Reference Resolvers that implement Java-specific static semantics (e.g., typing rules, scoping rules, referencing rules)



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JaMoPP Metamodel

commons

Commentable
NamedElement
NamespaceAwareElement

classifiers

Classifier, *ConcreteClassifier*
Implementor
Class, AnonymousClass,
Interface, Enumeration,
Annotation

containers

JavaRoot, CompilationUnit,
Package, EmptyModel

instantiations

Initializable, *Instantiation*
NewConstructorCall
ExplicitConstructorCall

types

Type, *TypedElement*
TypeReference
ClassifierReference
NamespaceClassifierReference
PrimitiveType
Boolean, Byte, Char, Double
Float, Int, Long, Short, Void

modifiers

Modifier, *Modifiable*
AnnotationInstanceOrModifier
AnnotableAndModifiable
Abstract, Final, Native
Public, Protected, Private
Static, Strictfp, Synchronized
Transient, Volatile

members

ExceptionThrower, *Member*
MemberContainer
AdditionalField, Constructor
EmptyMember, Field, Method
EnumConstant

arrays

ArrayTypable, ArrayDimension
ArrayInitializer, ArrayInstantiationBySize
ArrayInstantiationByValues, ArraySelector

statements

ForLoopInitializer
Statement
SwitchCase
Assert, Break, Block
CatchClause, Condition
Continue,
DefaultSwitchCase
DoWhileLoop
EmptyStatement
ExpressionStatement
ForLoop, ForEachLoop
JumpLabel
LocalVariableStatement
NormalSwitchCase
Return, Switch
SynchronizedBlock
Throw, TryBlock
WhileLoop

literals

Literal, *Self*
BooleanLiteral
CharacterLiteral
FloatLiteral
DoubleLiteral
DecimalFloatLiteral
DecimalDoubleLiteral
HexFloatLiteral
HexDoubleLiteral
IntegerLiteral
LongLiteral
DecimalIntegerLiteral
DecimalLongLiteral
HexIntegerLiteral
HexLongLiteral
OctalIntegerLiteral
OctalLongLiteral
NullLiteral, Super, This

parameters

Parameter,
Parametrizable,
OrdinaryParameter,
VariableLengthParameter

generics

TypeArgument
TypeArgumentable
TypeParametrizable
ExtendsTypeArgument
QualifiedTypeArgument
SuperTypeArgument
TypeParameter
UnknownTypeArgument

references

Reference, ArgumentList
ReferenceableElement
IdentifierReference
ReflectiveClassReference
PrimitiveTypeReference
StringReference
SelfReference

annotations

Annotable
AnnotationElementValuePair
AnnotationInstance
AnnotationMethod
AnnotationValue

variables

Variable
LocalVariable
AdditionalLocalVariable

imports

Import, *StaticImport*
ClassifierImport
PackageImport
StaticClassifierImport
StaticMemberImport

expressions

Expression, ExpressionList, AssignmentExpression, *AssignmentExpressionChild*, ConditionalExpression, *ConditionalExpressionChild*, ConditionalOrExpression, *ConditionalOrExpressionChild*, ConditionalAndExpression, *ConditionalAndExpressionChild*, InclusiveOrExpression, *InclusiveOrExpressionChild*, ExclusiveOrExpression, *ExclusiveOrExpressionChild*, AndExpression, *AndExpressionChild*, EqualityExpression, *EqualityExpressionChild*, InstanceOfExpression, *InstanceOfExpressionChild*, RelationExpression, *RelationExpressionChild*, ShiftExpression, *ShiftExpressionChild*, AdditiveExpression, *AdditiveExpressionChild*, MultiplicativeExpression, *MultiplicativeExpressionChild*, UnaryExpression, *UnaryExpressionChild*, *UnaryModificationExpression*, PrefixUnaryModificationExpression, SuffixUnaryModificationExpression, *UnaryModificationExpressionChild*, CastExpression, *PrimaryExpression*, NestedExpression

operators

Operator, *AdditiveOperator*, *AssignmentOperator*, *EqualityOperator*, *MultiplicativeOperator*, *RelationOperator*, *ShiftOperator*, *UnaryOperator*, *UnaryModificationOperator*
Assignment, AssignmentAnd, AssignmentDivision, AssignmentExclusiveOr, AssignmentMinus, AssignmentModulo, AssignmentMultiplication, AssignmentLeftShift
AssignmentOr, AssignmentPlus, AssignmentRightShift, AssignmentUnsignedRightShift, Equal, NotEqual, GreaterThan, GreaterThanOrEqual, LessThan, LessThanOrEqual
Addition, Subtraction, Division, Multiplication, Remainder, Complement, MinusMinus, Negate, PlusPlus, LeftShift, RightShift, UnsignedRightShift

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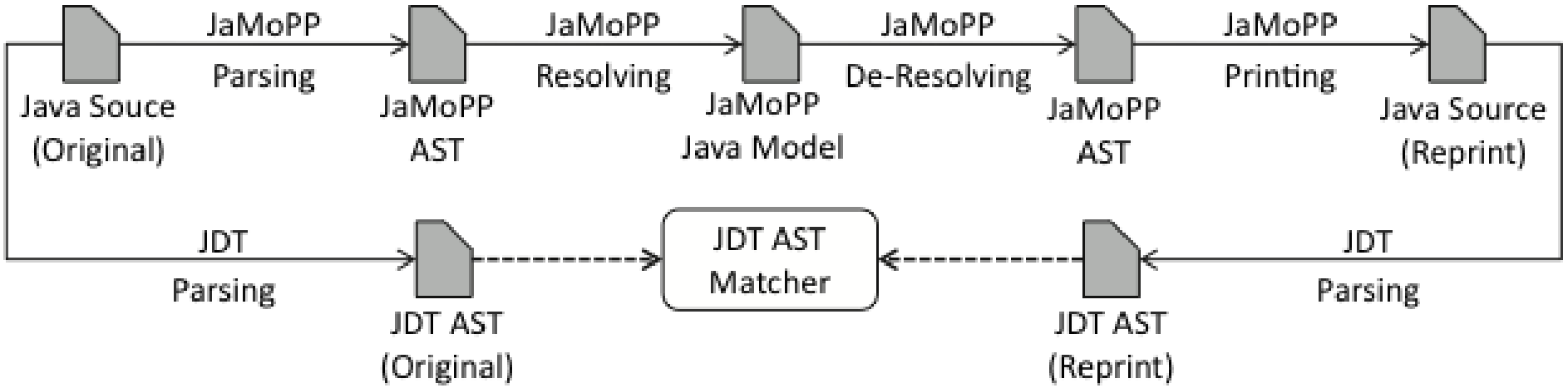
JaMoPP Testing



- Parsing public class A is easy, but parsing Java 5 is not (Unicode, Generics, Annotations and lots of weird things allowed by the JLS)
- JaMoPP Test suite:
  - 88.595 Java files (14.7 million non-empty lines including comments)
- Open Source projects:
  - AndroMDA 3.3, Apache Commons Math 1.2, Apache Struts 2.1.6, Apache Tomcat 6.0.18, Eclipse 3.4.1, Google Web Toolkit 1.11.3, JBoss 11.0.0 GA, Mantissa 7.2, Netbeans 6.5, Spring 3.0.0M1, Sun JDK 1.6.0 Update 7, XercesJ 2.9.1

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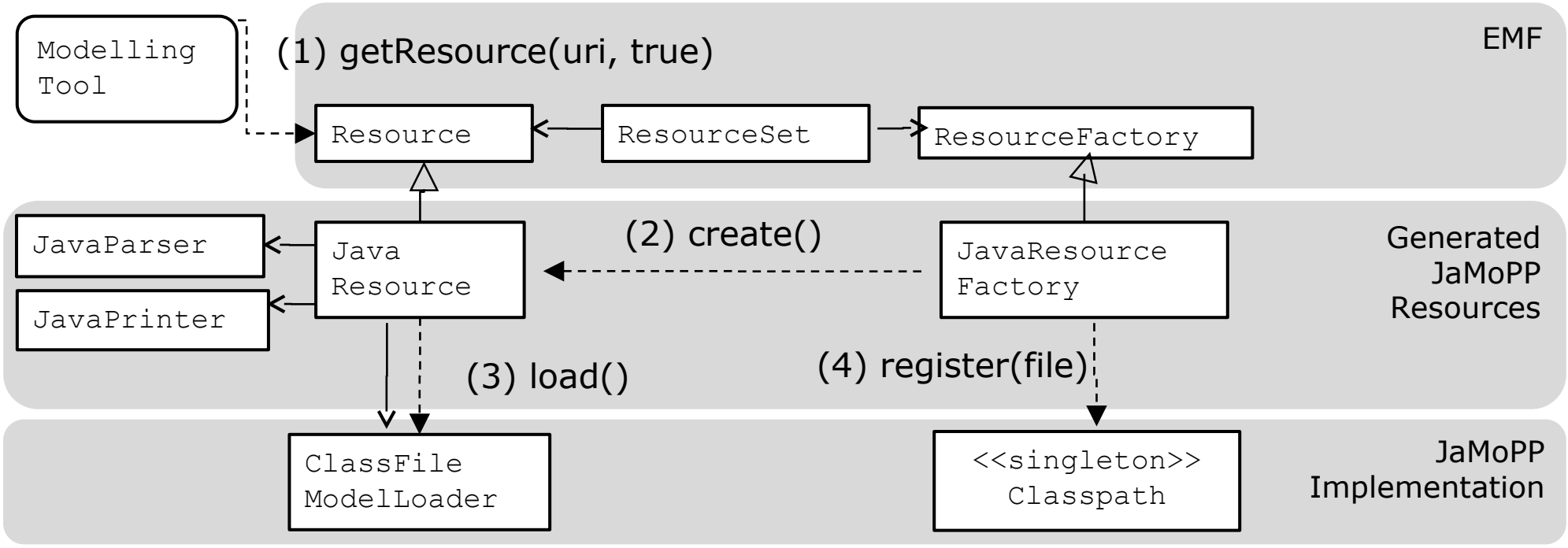
JaMoPP Tool Integration

- JaMoPP seamlessly and transparently integrates with arbitrary EMF-based Tools
- Parsing Java files to models and Printing Java Files is simple




```
ResourceSet rs = new ResourceSetImpl();
Resource javaResource = rs.getResource(URI.createFileURI("A.java"),true); //parsing
javaResource.save(); // printing
```

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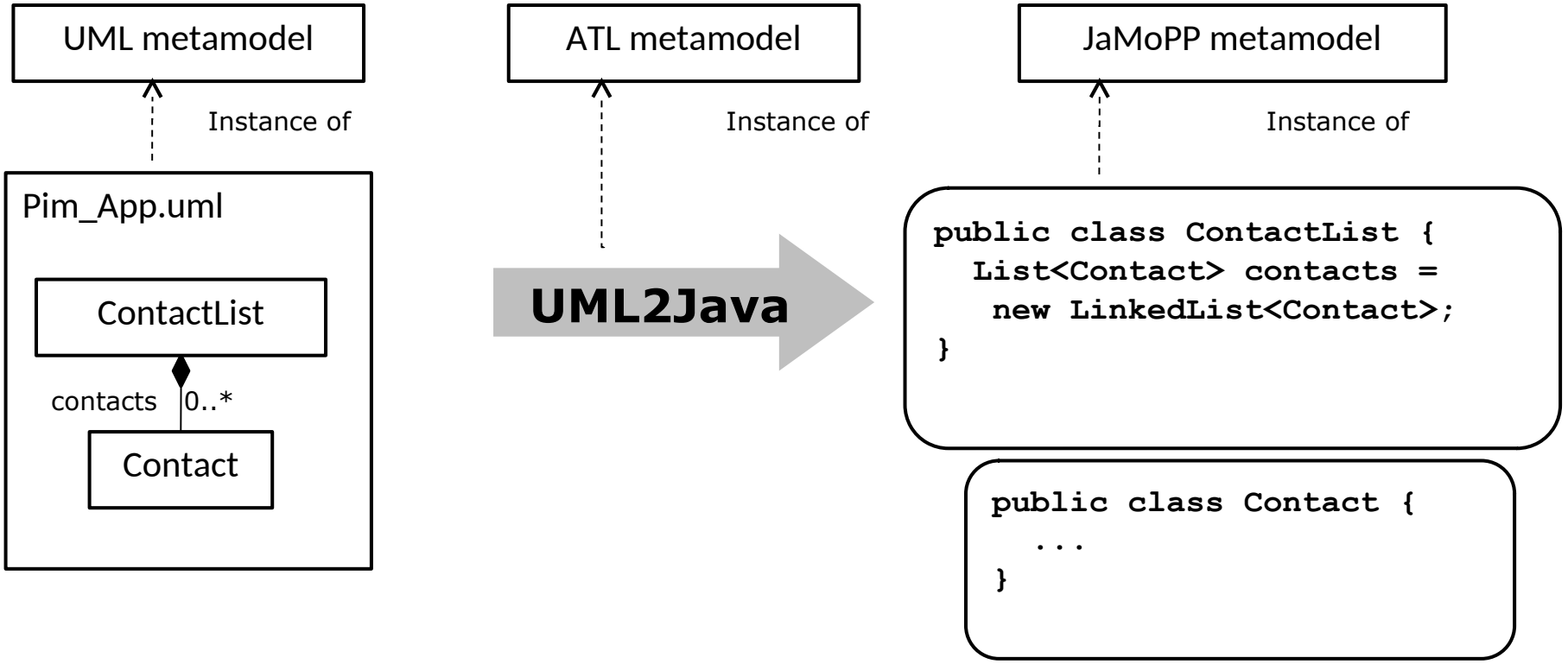
JaMoPP Application: Code Generation with the Code-To-Text Transformation Tool ATL

- Design UML model, apply M2M transformation, print JaMoPP model
- Syntactic and semantic correctness



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JaMoPP Application: Code Generation with the Code-To-Text Transformation Tool ATL

- Design UML model, apply M2M transformation, print JaMoPP model

```
rule Property {
   from umlProperty : uml!Property
   to javaField : java!Field (
     name <- umlProperty.name,
     type <- typeReference
   ),

   typeReference : java!TypeReference (
     target <- if (umlProperty.upper = 1) then umlProperty.type
       else
         java!Package.allInstances()->any(p | p.name = 'java.lang').compilationUnits->collect(
           cu | cu.classifiers)->flatten()->any(c | c.name = 'LinkedList')
       endif,
     typeArguments <- if (umlProperty.upper = 1) then
         Sequence{} -- empty type argument list
       else
         Sequence{typeArgument}
       endif
   ),

   typeArgument : java!QualifiedTypeArgument(
     target <- umlProperty.type
   )
 }
```

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JaMoPP Application: Code Analysis with the Query Langauge OCL

- Parse Java source files to model instances
- Run OCL queries to find undesired patterns

```
context members::Field inv:
   self->modifiers->select(m|m.oclIsKindOf(modifiers::Public))->size() = 0
```

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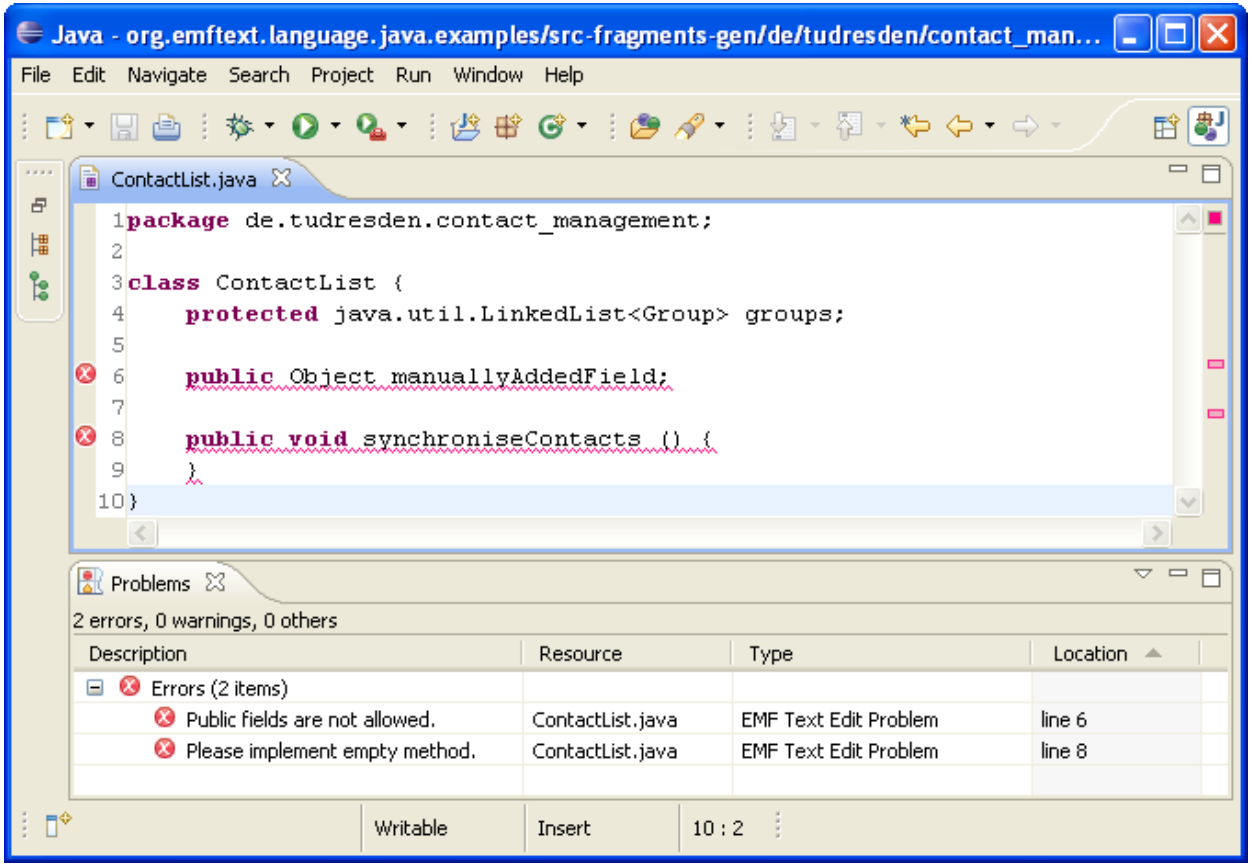
JaMoPP Application: Code Analysis (OCL)

- Parse Java source files to model instances
- Run OCL queries to find undesired patterns




```
context members::Field inv:
   self->modifiers->select(m|m.oclIsKindOf(modifiers::Public))->size() = 0
```

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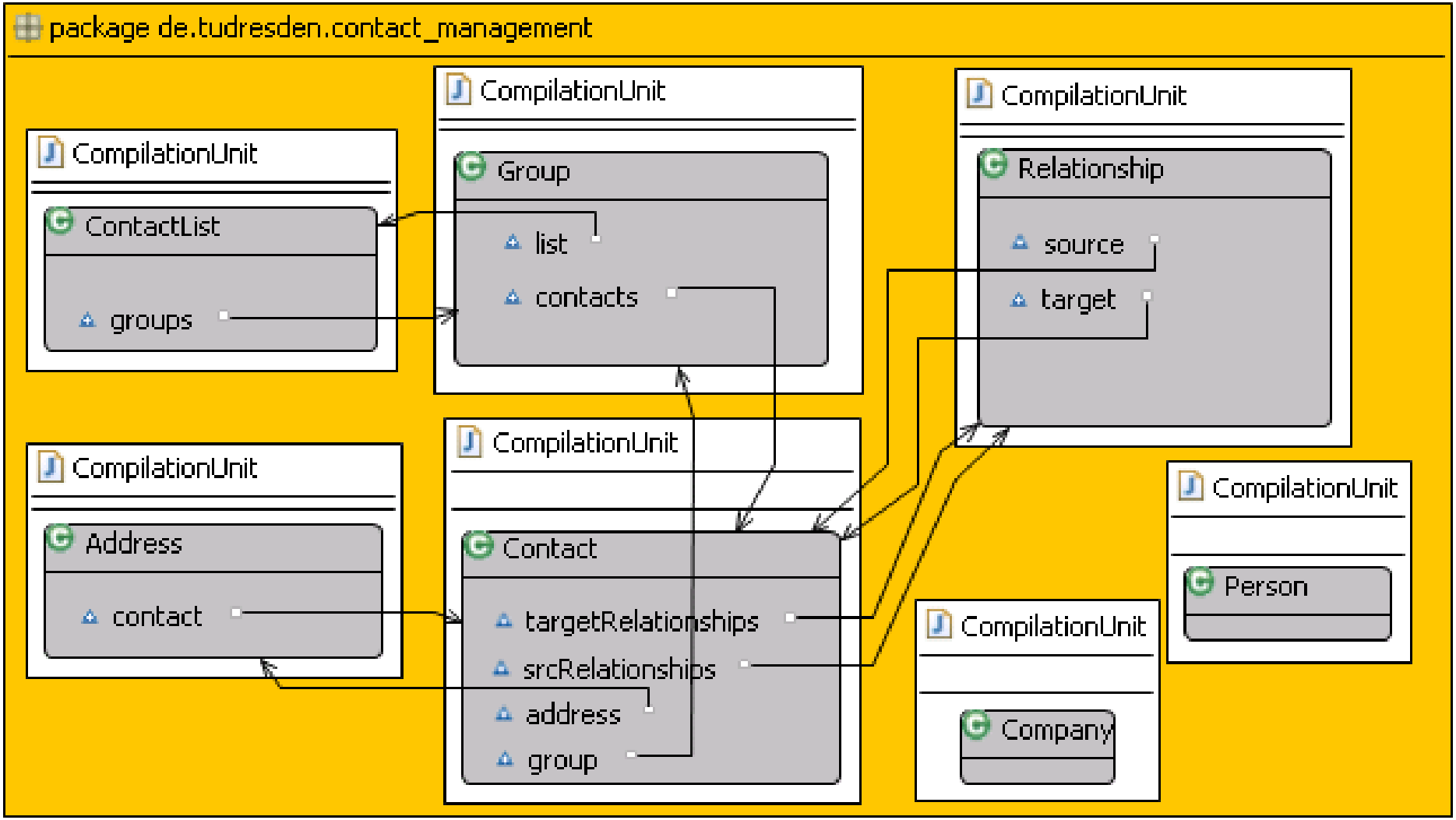
JaMoPP Application: Code Visualization (via Eclipse GMF)

- Create .gmfgraph, gmftool, and gmfmap model
- Generate Graphical Editor for Java



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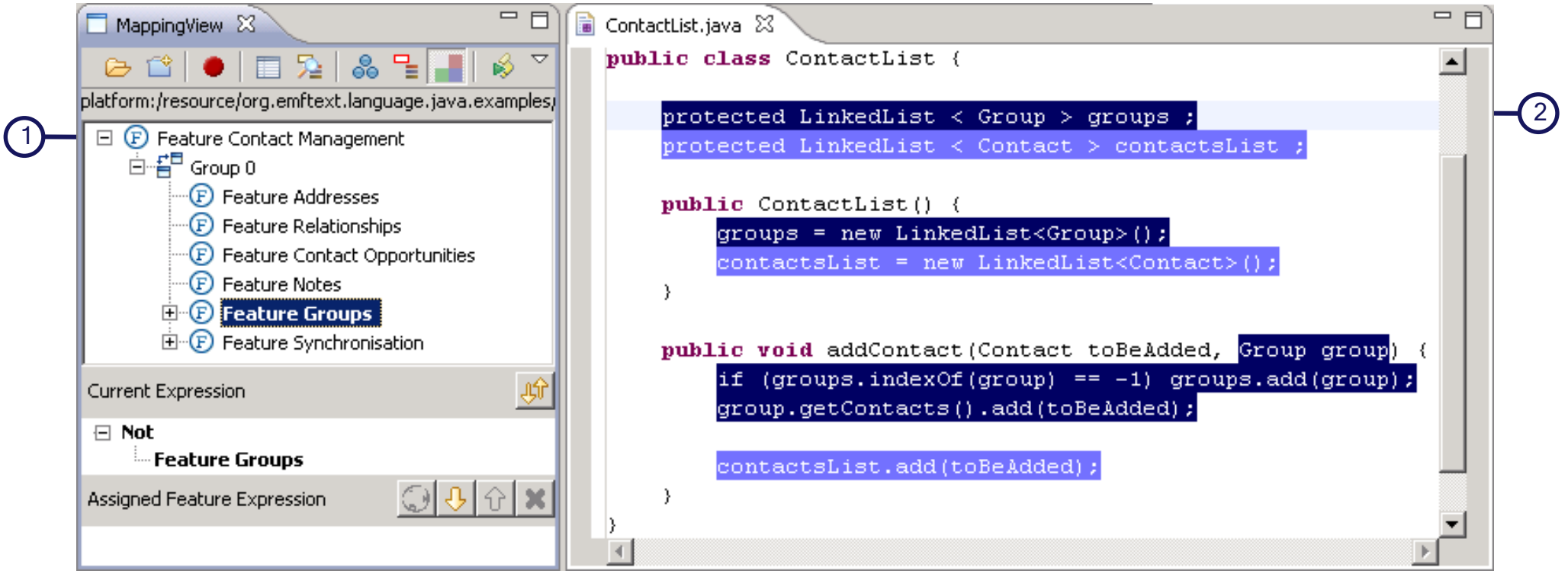
JaMoPP Application: Software Product Line Engineering (FeatureMapper)



1 – Feature Model

2 – EMFText Editor for Java (code for feature highlighted)

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11.4. Integrating DSLs and GPLs (Embedded DSL)

- http://www.jamopp.org/index.php/JaMoPP

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

JaMoPP Applications: What else?

- Round-trip Support for template-based code generators
- Refactoring, Optimization using model transformations
- Traceability-related activities
  - Certification (Map code to the model elements)
  - Impact analysis (How much of the code will change if I do this?)
- Embedded DSL
- Model-based compilation to byte code

- ...

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Using the DSL – Interpretation vs. Compilation

EMFText provides an extension point to perform interpretation (or compilation) whenever DSL documents change

To use the DSL we need to assign meaning by

- **Interpretation**: Traverse the DSL model and perform appropriate actions
- **Compilation**: Translate the DSL constructs to another (possibly executable) language
  - In principle compilation is an interpretation where the appropriate action is to emit code of the target language

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Embedded DSL “Embedded DieSeL”

- An **embedded domain-specific language (embedded DSL)** is a language extension of a general-purpose language (GPL), the base language
- An embedded SDL can be *interpreted* or *reduced (compiled to the core language)*
- Typesafe Template Languages
  - Same syntax as string-based templates

SandwichMaker.java_template

```
1<%TEMPLATE INPUT=
2  "http://www.emftext.org/language/sandwich::Recipe" %>
3
4public class SandwichMaker {
5  private class Instr {};
6  public Instr <%= "instructions" %> = new Instr();
7
8  private boolean cleanIngredients() {}
9  private void addSingleIngredient() {}
10
11  public void addIngredients() {
12    <%FOR "engredients" %> // typo 'ingredients'
13      addSingleIngredient();
14    <%ENDFOR%>
15  }
16
17  public void makeSandwich() {
18    <%IF "instructions->exists(i|i.oclIsKindOf(Clean))" %>
19      boolean success = cleanIngredients();
20    <%ENDIF%>
21
22    if (!success) return; // May not be available
23    addIngredients();
24  }
25}
```

Problems

3 errors, 0 warnings, 0 others

Description	Loc...
Errors (3 items)	
The expression in the placeholder has wrong type (was org.eclipse.ocl.ecore.impl.Order	line 6
The expression "engredients" is invalid (Unrecognized variable: (engredients)).	line 12
ReferenceableElement 'success' not declared	line 22

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Extended Code Generation for a Embedded DSL

- An **Reducer** for an **embedded DSL** is a set of additional code generation rules
  - extending the rule set of the code generation of the base language
- Reducers should be composed modularly with the modules of the base language

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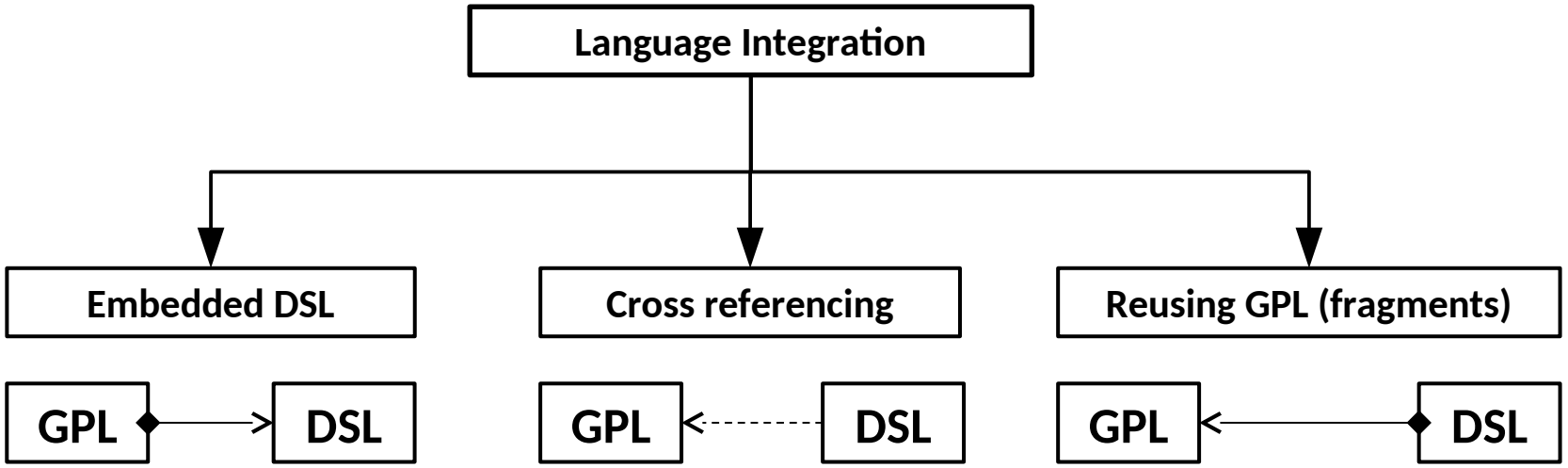
11.4.2 Language Integration by Metamodel and Grammar Inheritance

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

Integrating DSLs and GPLs

- Different integration scenarios



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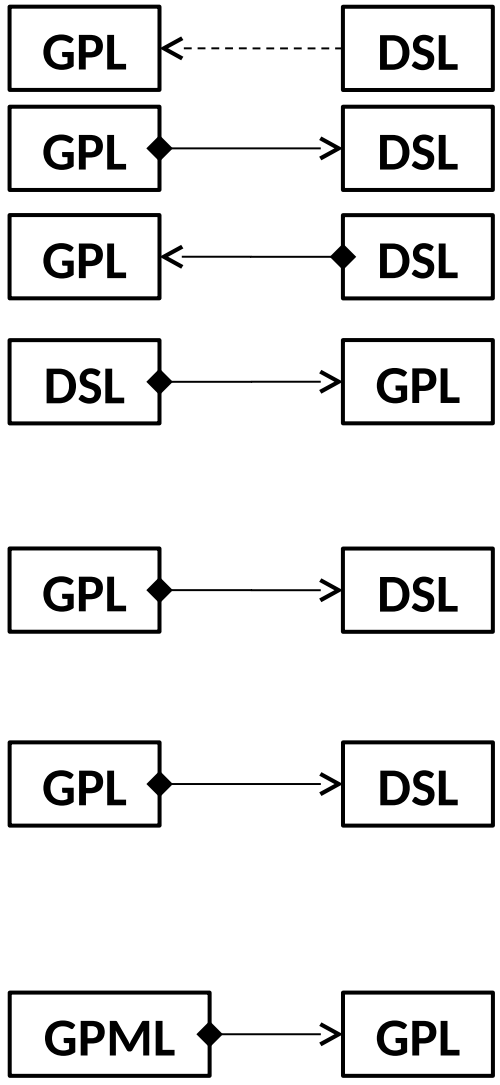
Language Integration Examples

- FormsExtension
- FormsEmbedded
- JavaForms
- eJava
  - Provides metamodels with Eoperations
  - implementations without touching the generated java files
- JavaTemplate
  - Syntax safe templates with JaMoPP
- PropertiesJava
  - Experimental extension for Java to define C# like properties
- JavaBehaviour4UML
  - An integration of JaMoPP and the UML
  - Methods can be directly added to Classes in class diagrams



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Thank you!

Questions?

New URL: https://github.com/DevBoost/EMFText

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11. Bridging the Technical Spaces Grammarware and EMOFware using EMFText

Florian Heidenreich, Jendrik Johannes, Sven Karol,
Mirko Seifert, Christian Wende (DevBoost)
Uwe Aßmann

Version 21-0.1, 10/22/12

1) What is a DSL?
2) How to build a DSL
    1) Defining/Using a Metamodel
    2) Syntax Definition
        1) Generating an initial syntax (HUTN)
    3) Refining the syntax
3) Advanced features of EMFText
    1) Mapping text to data types
    2) Reference resolving
    3) Syntax modules (Import and Reuse)
    4) Interpretation vs. Compilation
4) Other DSL examples in the Zoo
5) Appendix: Integrating DSLs and GPLs

Obligatory LIterature

- Florian Heidenreich, Jendrik Johannes, Sven Karol, Mirko Seifert, and Christian Wende. Model-based language engineering with EMFText. In Ralf Lämmel, João Saraiva, and Joost Visser, editors, GTTSE, volume 7680 of Lecture Notes in Computer Science, pages 322-3411. Springer, 2011.

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Recommended Literature

EMFText is on gitlab, by our start-up, DevBoost
www.devboost.de
https://github.com/DevBoost/

- Many tools under https://github.com/DevBoost/
- Florian Heidenreich, Jendrik Johannes, Sven Karol, Mirko Seifert and Christian Wende. Derivation and Refinement of Textual Syntax for Models. In Proc. of the 5th European Conference on Model-Driven Architecture Foundations and Applications (ECMDA-FA 2009).
- Mirko Seifert and Christian Werner. Specification of Triple Graph Grammar Rules using Textual Concrete Syntax. 7th International Fujaba Days, 2009
- Florian Heidenreich, Jendrik Johannes, Mirko Seifert and Christian Wende. Construct to Reconstruct - Reverse Engineering Java Code with JaMoPP. In Proc. of the International Workshop on Reverse Engineering Models from Software Artifacts (R.E.M.'09).
- Florian Heidenreich, Jendrik Johannes, Mirko Seifert and Christian Wende. Closing the Gap between Modelling and Java Tool demonstration at the 2nd International Conference on Software Language Engineering (SLE'09).
- Florian Heidenreich, Jendrik Johannes, Mirko Seifert, Christian Wende and Marcel Böhme. Generating Safe Template Languages. In Proc. of the 8th International Conference on Generative Programming and Component Engineering (GPCE 2009).
- Christian Wende and Florian Heidenreich. A Model-based Product-Line for Scalable Ontology Languages. In Proc. of the 1st International Workshop on Model-Driven Product-Line Engineering (MDPLE 2009) collocated with ECMDA-FA 2009. Enschede, The Netherlands, June 2009.
- Mirko Seifert and Roland Samlaus. Static Source Code Analysis using OCL. In Proc. of OCL Workshop 2008 at MODELS 2008
- Jakob Henriksson, Florian Heidenreich, Jendrik Johannes, Steffen Zschaler and Uwe Aßmann. Extending Grammars and Metamodels for Reuse -- The Reuseware Approach. IET Software Journal 2008.

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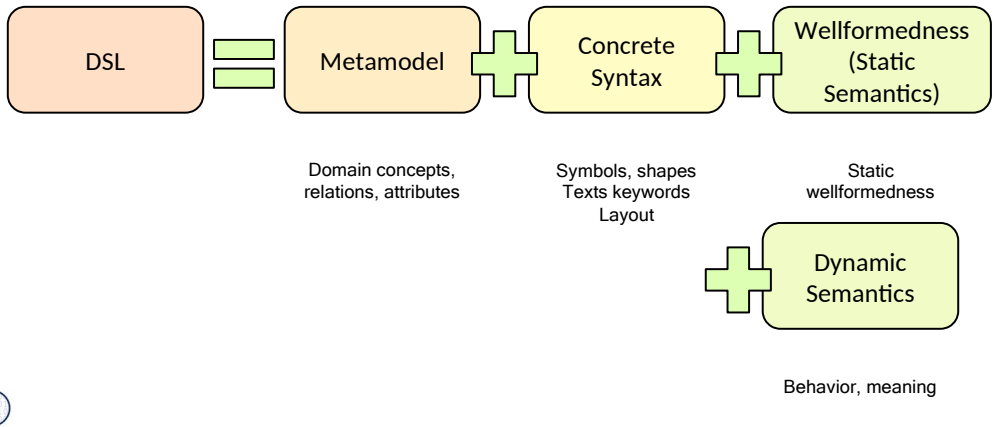
11.1 What is a Domain-Specific Language (DSL)?

What's in a Domain-Specific Language (DSL)?

- The core of a DSL is a metamodel on M2 derived from the lifted core metamodel (e.g., EMOF)



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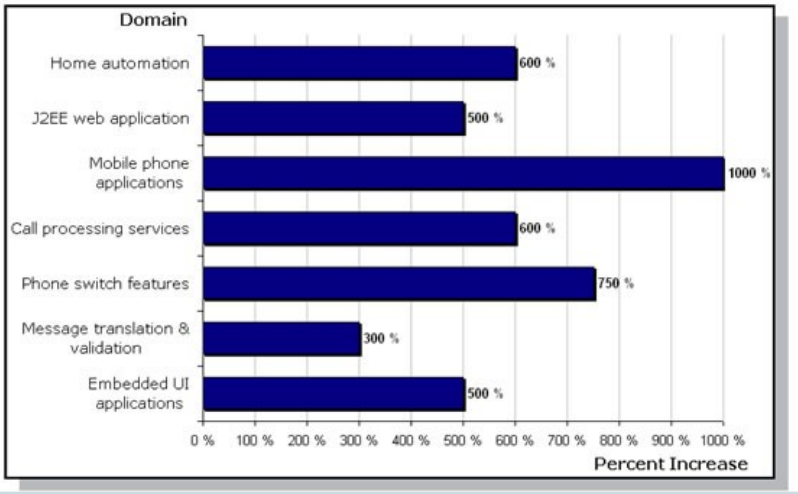
Productivity Gains with DSL



Juha-Pekka Tolvanen. Domain-Specific Modeling for Full Code Generation. January 2010. Vol. 12, Number 4. http://journal.thedacs.com/issue/52/144

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Motivation – Why Metamodel-Based DSLs?

Pros

+ Enhance productivity, reliability, maintainability and portability
+ Co-evolution is simpler, because metaprograms may influence M1
+ Use the concepts and idioms of a domain in a metamodel
  - Domain experts can understand, validate and modify DSL programs (good for communication between domain experts and programmers)
  - Higher level of abstraction
  - Expressiveness in a domain
+ Concise and self-documenting
+ Embody domain knowledge, enabling the conservation and reuse of this knowledge

But:

- Costs of design, implementation and maintenance
- Costs of education for users
- Limited availability of DSLs
- Evolution is not easy to organize

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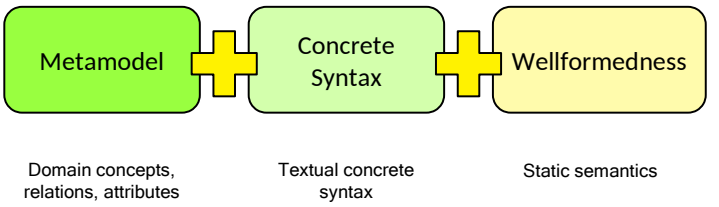
What is a Textual Domain-Specific Language (DSL)?

- The **EMFText tool suite** relates a concrete syntax specification (grammar in EBNF) to a EMOF/Ecore-based metamodel.
- From this language mapping, printers, parsers and editors for a DSL can be generated



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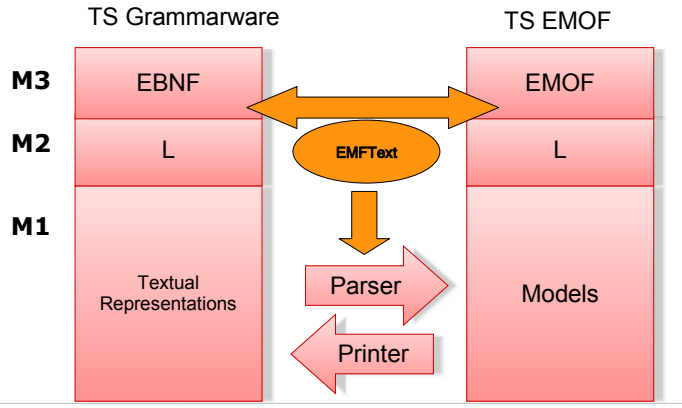
Textual DSL rely on a Transformation Bridge between the Technical Spaces EMOF and Grammarware

- The **EMFText tool suite** relates a concrete syntax specification (grammar in EBNF) to a EMOF/Ecore-based metamodel.
- From this language mapping, printers (unparsers), parsers and editors are generated
- EMFText can be used to produce normative concrete syntax for exchange formats



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EMFText Motivation – Why Textual syntax?

Why use textual syntax for models?

- Readability
- Diff/Merge/Version Control
- Evolution
- Tool autonomy
- Quick model instantiation

Why create models from text?

- Tool reuse (e.g., to perform transformations (ATL) or analysis (OCL))
- Know-how reuse
- Explicit representation of text document structure
- Tracing software artifacts
- Graphs instead of strings

Be aware: exchange syntax is like a textual DSL

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EMFText Philosophy and Goals

Design principles:

- Convention over Configuration
- Provide defaults wherever possible
- Allow customization for all parts of a syntax

Syntax definition should be

- Simple and easy for small DSLs
- Yet powerful for complex languages

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EMFText Features

- **Generation Features**
  - Generation of independent code
  - Generation of Default Syntax Grammar (via default language mapping)
  - Customizable Code Generation
- **Specification Features**
  - Modular Specification
  - Default Reference Resolving
  - Comprehensive Syntax Analysis
- **Editor Features**
  - Code Completion, Customizable Syntax and Occurence Highlighting, Code Folding, Error Marking, Hyperlinks, Text Hovers, Outline View, ...
- **Other Highlights**
  - ANT Support, Post Processors, Builder, Interpreter and Debugger Stubs, Quick Fixes
  - Full Java support (JaMOPP)

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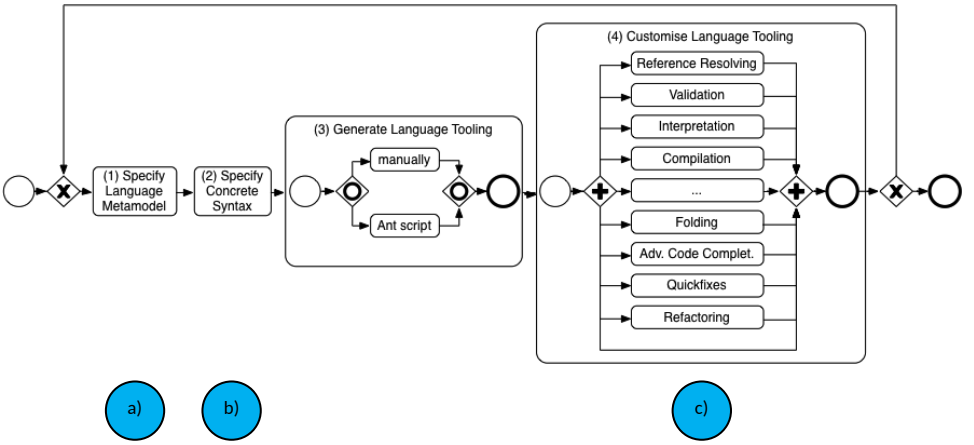
11.2 How to Build a DSL with EMFText

EMFText Language Development Process



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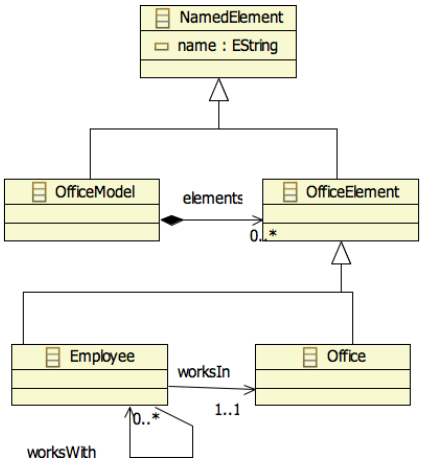
How to build a DSL – Metamodel

a)



Creating a new Metamodel:

- Define concepts, relations and properties in an Ecore model
- Existing Metamodels can be imported (e.g., UML, Ecore, …)

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How to build a DSL – Metamodel

a)

Repetition: Metamodel elements (EMF concepts):

- Classes
- Data Types
- Enumerations

- Attributes
- References (Containment, Non-containment)
- Cardinalities

- Inheritance

- The Office DSL is a *Material* metamodel, because offices are treated as data

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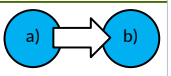
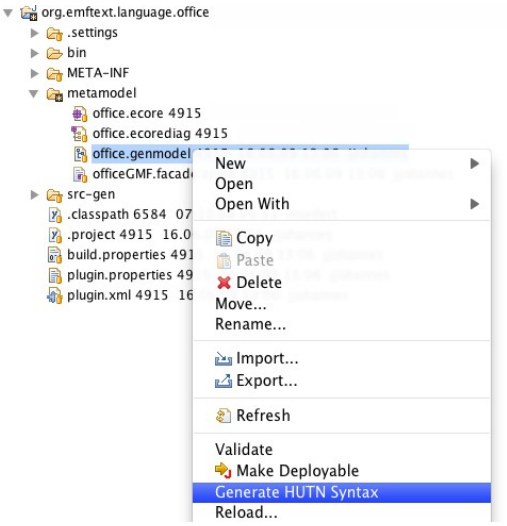
Generate Initial Syntax (Human Usable Text Notation)





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Initial HUTN Syntax – Generated Grammar

b)

- All metaclasses of the EMOF metamodel become nonterminals in the text grammar

office.cs

```
SYNTAXDEF office
FOR <http://emftext.org/office>
START OfficeModel

TOKENS{
    DEFINE COMMENT$'//'(~('\n'|'\r'|'\ufffe'))*$;
    DEFINE INTEGER$('-')?('1'..'9')('0'..'9')*|'0'$;
    DEFINE FLOAT$('-')?(('1'..'9') ('0'..'9')* | '0') '.' ('0'..'9')+ $;
}

TOKENSTYLES{
    "OfficeModel" COLOR #7F0055, BOLD;
    "name" COLOR #7F0055, BOLD;
    "elements" COLOR #7F0055, BOLD;
    "Employee" COLOR #7F0055, BOLD;
    "worksIn" COLOR #7F0055, BOLD;
    "worksWith" COLOR #7F0055, BOLD;
    "Office" COLOR #7F0055, BOLD;
}

RULES{

    OfficeModel::= "OfficeModel" "{" ( "name" ":" name['"','"'] | "elements" ":" elements )* "}" ;

    Employee::= "Employee" "{" ( "name" ":" name['"','"'] | "worksIn" ":" worksIn[]| "worksWith" ":" worksWith[] )* "}" ;

    Office::= "Office" "{" ( "name" ":" name['"','"'] )* "}" ;

}
```

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Initial, Generated HUTN Syntax – Example Document

b)

st.office

```
OfficeModel {
    name : "SoftwareTechnology"

    elements :
        Office {
            name : "INF2080"
        }

    elements :
        Office {
            name : "INF2084"
        }

    elements :
        Employee {
            name : "Florian"
            worksIn : INF2080
            worksWith : Jendrik
        }

    elements :
        Employee {
            name : "Jendrik"
            worksIn : INF2084
            worksWith : Florian
        }
}
```

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Syntax Refinement: User Modifies Grammar to Remove Brackets


```
//*****************************************************************************
// Copyright (c) 2006-2010
// Software Technology Group, Dresden University of Technology
//
// All rights reserved. This program and the accompanying materials
// are made available under the terms of the Eclipse Public License v1.0
// which accompanies this distribution, and is available at
// http://www.eclipse.org/legal/epl-v10.html
//
// Contributors:
//   Software Technology Group - TU Dresden, Germany
//      - initial API and implementation
// MODIFIED, SIMPLIFIED GRAMMAR
// *****************************************************************************/
SYNTAXDEF office
FOR <http://emftext.org/office>
START OfficeModel
OPTIONS {
        licenceHeader ="../../org.dropsbox/licence.txt";
        generateCodeFromGeneratorModel = "true";
        disableLaunchSupport = "true";
        disableDebugSupport = "true";
}
RULES {
        OfficeModel ::= "officemodel" name[]
                                        "{" elements* "}" ;

        Office ::= "office" name[];

        Employee ::= "employee" name[]
                                "works" "in" worksIn[]
                                "works" "with"
                                worksWith[] ("," worksWith[])* ;
}
```

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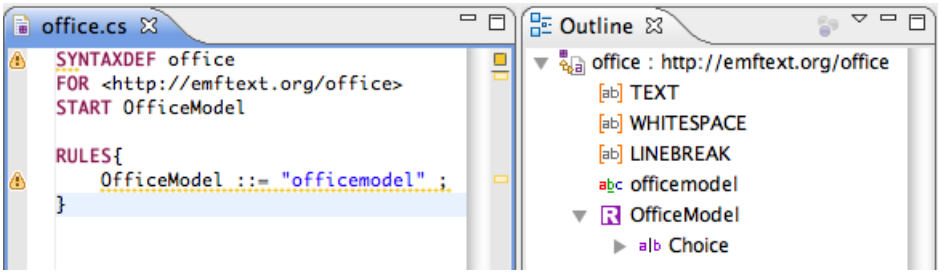
Syntax Refinement – The Concrete Syntax Language CS

b)

Structure of a .cs file:

- Header
  - File extension
  - Metamodel namespace URI, *location*
  - Start element(s)
  - *Imports (Metamodels, other syntax definitions)*
- *Options*
- *Token Definitions*
- Syntax Rules



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Syntax Refinement – Syntax Rules in EBNF

b)

- The structure of CS is defined in EBNF (Extended Backus-Naur Form), the dominating metalanguage of the Grammarware technical space

- **Definition elements in EBNF rules:**
  - Static strings (keywords) "public"
  - Choices a|b
  - Multiplicities +,*
  - Compounds (ab)
  - Terminals a[] (Non-containment references, attributes)
  - Non-terminals a (Containment references)

- **Language mapping:** One syntax rule per metaclass (concept mapping):
  - This defines the *language mapping* between EBNF and EMF metaclasses
  - Syntax: `MetaClassName ::= Syntax Definition ;`
- All concept mappings define a *language mapping*

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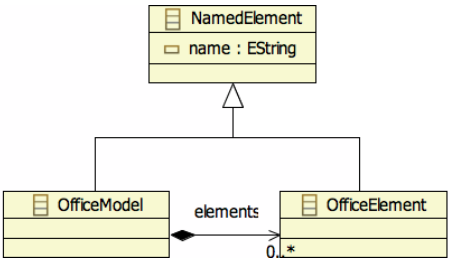
Customizing Syntax Rules - Examples

b)

// EMOF Metamodel




```
// Grammar Rule
OfficeModel ::= "officemodel" name[]
        "{" elements* "}" ;
```

```
// Textual model
officemodel SoftwareTechnology {
  ...
}
```

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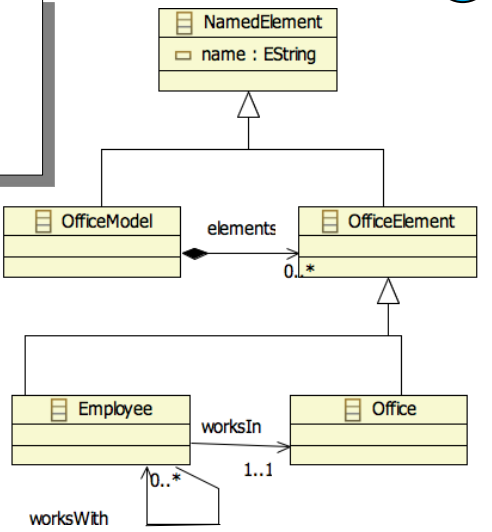
Customizing Syntax Rules - Examples


```
RULES {
    OfficeModel ::= "officemodel" name[]"{" elements* "}" ;

    Office ::= "office" name[];

    Employee ::= "employee" name[]
                 "works" "in" worksIn[]
                 "works" "with"
                    worksWith[] ("," worksWith[])* ;
}
```

```
// Text
officemodel SoftwareTechnology {
  office INF2080
  employee Florian
      works in INF2018
}
```

b)

// EMOF Metamodel



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Grammar of Complete Customized Syntax

b)

office.cs

```
SYNTAXDEF office
FOR <http://emftext.org/office>
START OfficeModel

OPTIONS {
    generateCodeFromGeneratorModel = "true";
}

RULES {
    OfficeModel ::= "officemodel" name[]
                    "{" elements* "}" ;

    Office ::= "office" name[];

    Employee ::= "employee" name[]
                 "works" "in" worksIn[]
                 "works" "with"
                 worksWith[] ("," worksWith[])* ;
}
```

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DSM: Generic Syntax vs. Custom Syntax

b)

st.office

```
OfficeModel {
    name : "SoftwareTechnology"

    elements :
        Office {
            name : "INF2080"
        }

    elements :
        Office {
            name : "INF2084"
        }

    elements :
        Employee {
            name : "Florian"
            worksIn : INF2080
            worksWith : Jendrik
        }

    elements :
        Employee {
            name : "Jendrik"
            worksIn : INF2084
            worksWith : Florian
        }
}
```

st.office

```
officemodel SoftwareTechnology {

    office INF2080

    office INF2084

    employee Florian
        works in INF2080
        works with Jendrik

    employee Jendrik
        works in INF2084
        works with Florian
}
```

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11.3. Advanced Features of EMFText

Advanced Features – Attribute Mapping

c)

- Putting strings into EString attributes is easy
- How about EInt, EBoolean, EFloat, ..., custom data types?
- Solution A: Default mapping: The generated classes use the conversion methods provided by Java (java.lang.Integer, Float etc.)
- Solution B: Customize the mapping using a token resolver

```
// resolver interface looks up a lexem in the context
// example implementation for TRUE == yes
public void resolve(String lexem,
        EStructuralFeature feature,
        ITokenResolveResult result) {
    if ("yes".equals(lexem)) result.setResolvedToken(Boolean.TRUE);
    else result.setResolvedToken(Boolean.FALSE);
}
public String deResolve(Object value,
      EStructuralFeature feature,
      EObject container) {
   if (value == Boolean.TRUE) return "yes"; else return "no";
}
```

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Advanced Features – Resolving Cross References

c)

Well, quite similar to attribute mappings:

- **Solution A**: Default resolvingSearches for matching elements that have an ID attribute, a name attribute or a single attribute of type EString and picks the first
  - (Works well for simple DSLs without scoping rules)

- **Solution B:** Custom resolvingChange the generated resolver class (implements IReferenceResolver<ContainerType, ReferenceType>)
  - For examples see the resolvers for the Java language

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Advanced Features – Syntax Modules for Language Composition

c)

- Import Metamodels optionally with syntax
- Extend, Combine, Compose existing DSLs
- Create embedded DSLs (e.g., for Java)
- Create a template language from your DSL
- …
- Attention: new URL: https://github.com/DevBoost/EMFText

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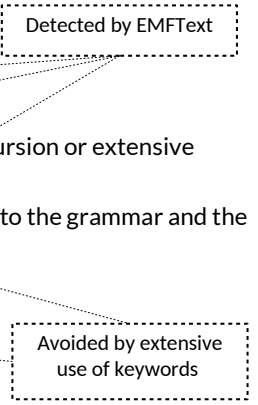
Pitfalls of Language Composition (with EMFText)

Syntax and model extensions can be non-trivial

In EMFText problems may be caused by

- Unexpected inclusions between token definitions
- Intersections between token definitions (partial overlaps)
- Problems with the underlying parser generator, e.g. left-recursion or extensive backtracking
- Ambiguous grammars (may require non monotonic changes to the grammar and the metamodels)
- Interference between reference resolvers
- Different language semantics



Alternative parsing technologies: Scannerless Parsing, Context-Aware Scanning, SDF/SGLR, MPS, Packrat Parsing, Parsing Expression Grammars ….

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The EMFText Syntax Zoo (>90 residents)

- Ecore, KM3 (Kernel Meta Metamodel)
- Quick UML, UML Statemachines
- Java 5 (complete: JaMOPP), C# (in progress)

- Feature Models
- Regular Expressions
- OWL2 Manchester Syntax

- Java Behavior4UML
- DOT (Graphviz language)

…and lots of example DSLs

https://github.com/DevBoost/EMFText-Zoo

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Conclusion

- Few concepts to learn before using EMFText
- Creating textual syntax for new languages is easy, for existing ones it is harder, but possible (we did Java)
- Rich tooling can be generated from a syntax definition
- Textual and graphical syntax can complement each other (e.g., to support version control)
- Semantics (Interpretation/Compilation) must be defined manually – At most it can be reused

Language is the blood of the soul into which thoughts run
and out of which they grow.

(Oliver Wendell Holmes)

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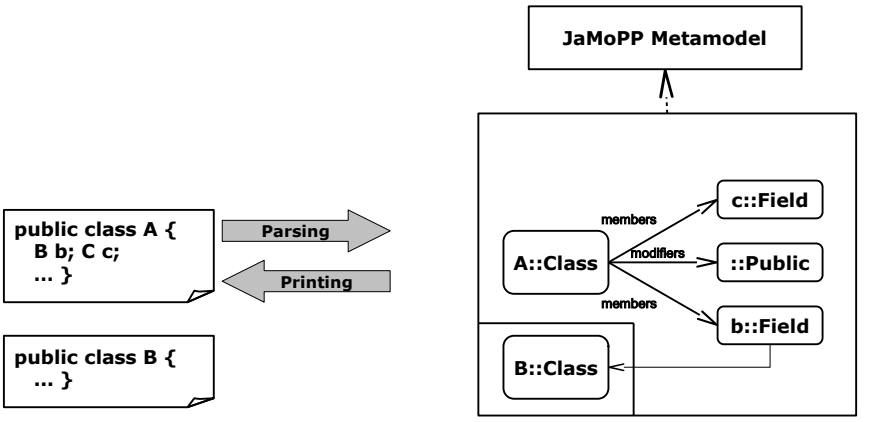
11.4 Use EMFText for Embedded DSL

- Def.: An ***embedded DSL*** is a DSL extending a general-purpose language (GPL)

JaMoPP: Lifting Java to DSLs

https://github.com/DevBoost/JaMoPP

- Ingredients:
  - Ecore Metamodel for Java 5 (153 concrete, 80 abstract classes)
  - EMFText .cs definition for each concrete class



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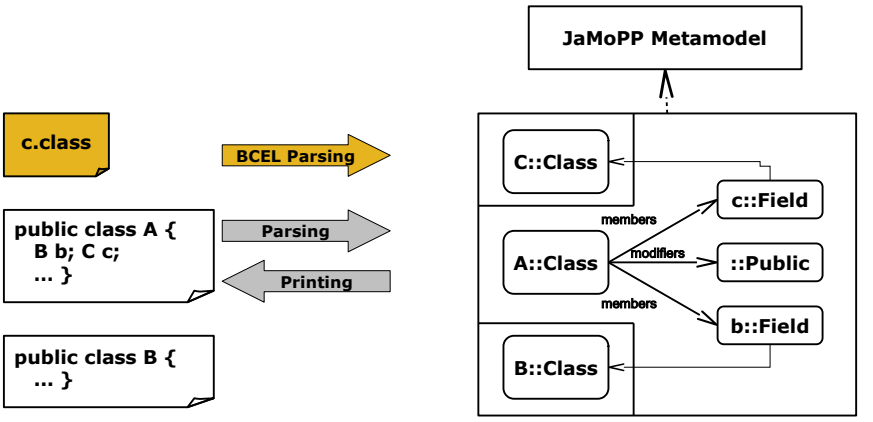
JaMoPP: Lifting Java to DSLs

- Ingredients:
  - Ecore Metamodel for Java 5 (153 concrete, 80 abstract classes)
  - EMFText .cs definition for each concrete class
  - BCEL Bytecode-Parser – to handle third-party libraries



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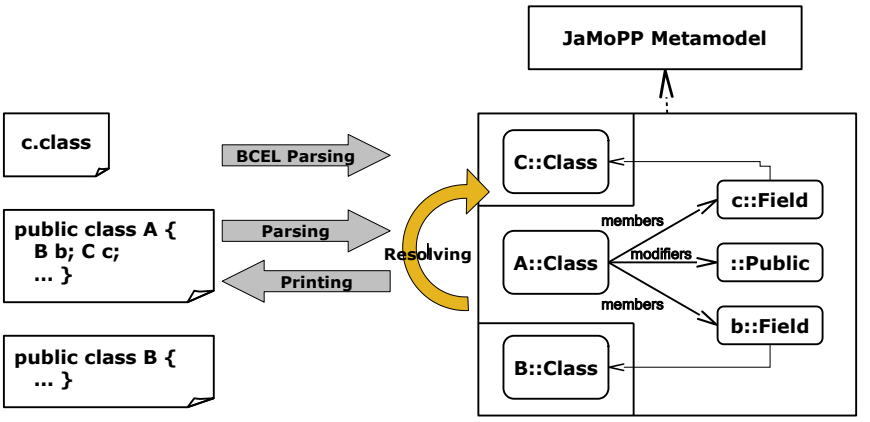
JaMoPP: Lifting Java to DSLs

- Reference Resolvers that implement Java-specific static semantics (e.g., typing rules, scoping rules, referencing rules)



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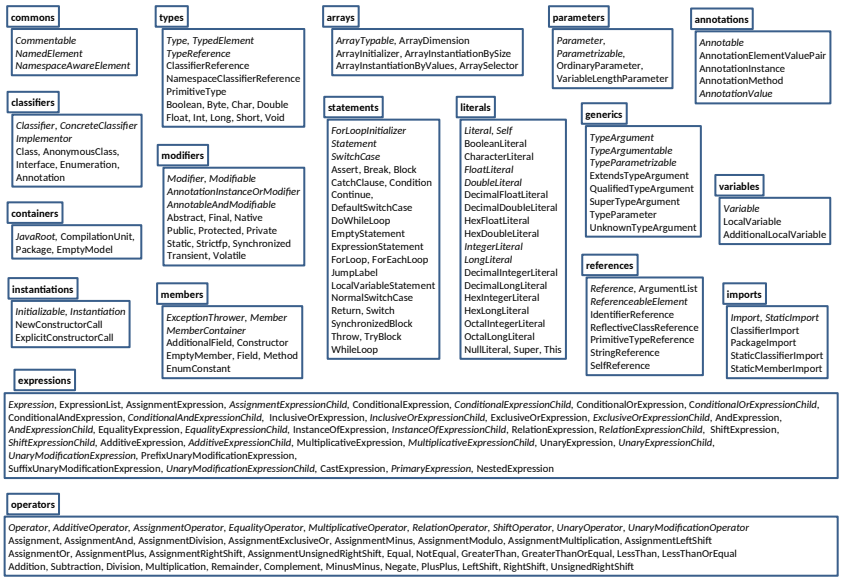
JaMoPP Metamodel



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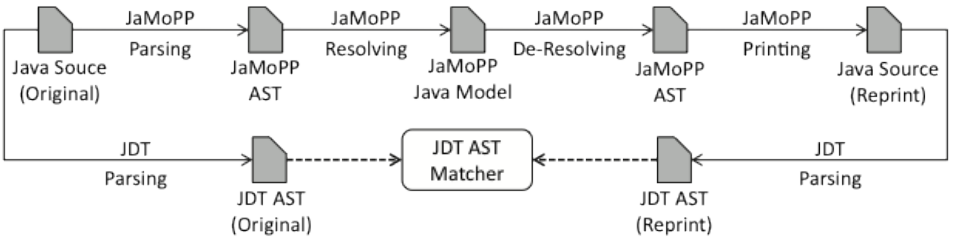
JaMoPP Testing



- Parsing public class A is easy, but parsing Java 5 is not (Unicode, Generics, Annotations and lots of weird things allowed by the JLS)
- JaMoPP Test suite:
  - 88.595 Java files (14.7 million non-empty lines including comments)
- Open Source projects:
  - AndroMDA 3.3, Apache Commons Math 1.2, Apache Struts 2.1.6, Apache Tomcat 6.0.18, Eclipse 3.4.1, Google Web Toolkit 1.11.3, JBoss 11.0.0 GA, Mantissa 7.2, Netbeans 6.5, Spring 3.0.0M1, Sun JDK 1.6.0 Update 7, XercesJ 2.9.1

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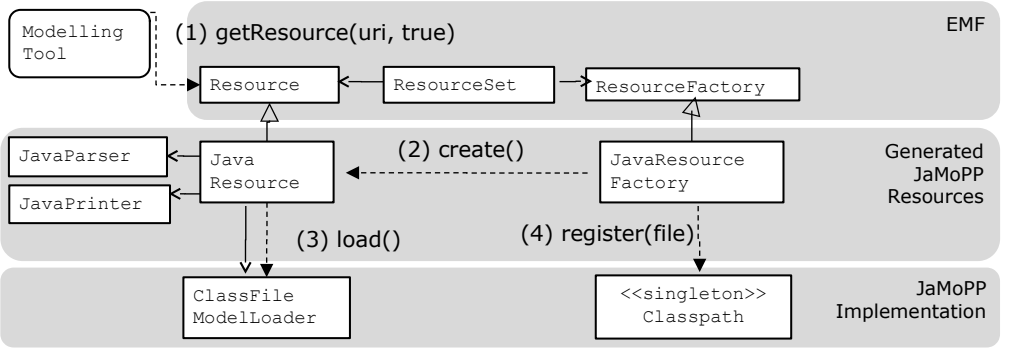
JaMoPP Tool Integration

- JaMoPP seamlessly and transparently integrates with arbitrary EMF-based Tools
- Parsing Java files to models and Printing Java Files is simple




```
ResourceSet rs = new ResourceSetImpl();
Resource javaResource = rs.getResource(URI.createFileURI("A.java"),true); //parsing
javaResource.save(); // printing
```

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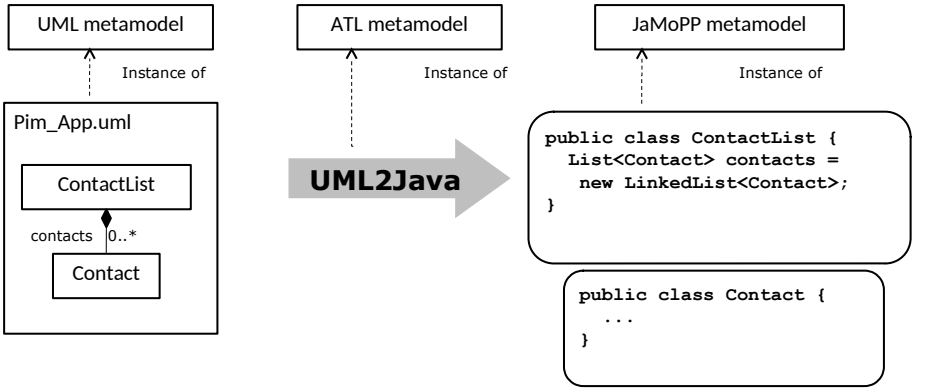
JaMoPP Application: Code Generation with the Code-To-Text Transformation Tool ATL

- Design UML model, apply M2M transformation, print JaMoPP model
- Syntactic and semantic correctness



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JaMoPP Application: Code Generation with the Code-To-Text Transformation Tool ATL

- Design UML model, apply M2M transformation, print JaMoPP model

```
rule Property {
   from umlProperty : uml!Property
   to javaField : java!Field (
     name <- umlProperty.name,
     type <- typeReference
   ),

   typeReference : java!TypeReference (
     target <- if (umlProperty.upper = 1) then umlProperty.type
       else
         java!Package.allInstances()->any(p | p.name = 'java.lang').compilationUnits->collect(
           cu | cu.classifiers)->flatten()->any(c | c.name = 'LinkedList')
       endif,
     typeArguments <- if (umlProperty.upper = 1) then
         Sequence{} -- empty type argument list
       else
         Sequence{typeArgument}
       endif
   ),

   typeArgument : java!QualifiedTypeArgument(
     target <- umlProperty.type
   )
 }
```

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JaMoPP Application: Code Analysis with the Query Langauge OCL

- Parse Java source files to model instances
- Run OCL queries to find undesired patterns

```
context members::Field inv:
   self->modifiers->select(m|m.oclIsKindOf(modifiers::Public))->size() = 0
```

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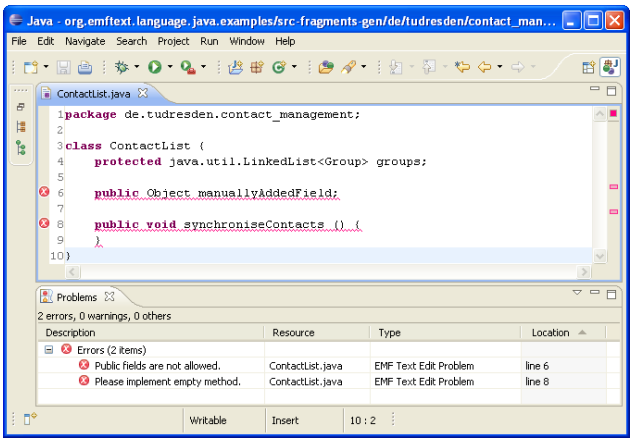
JaMoPP Application: Code Analysis (OCL)

- Parse Java source files to model instances
- Run OCL queries to find undesired patterns




```
context members::Field inv:
   self->modifiers->select(m|m.oclIsKindOf(modifiers::Public))->size() = 0
```

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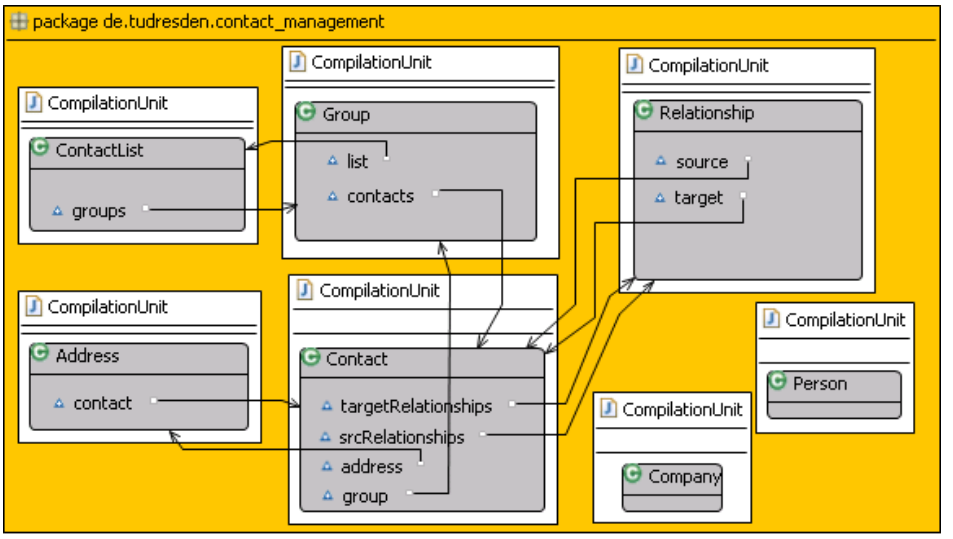
JaMoPP Application: Code Visualization (via Eclipse GMF)

- Create .gmfgraph, gmftool, and gmfmap model
- Generate Graphical Editor for Java



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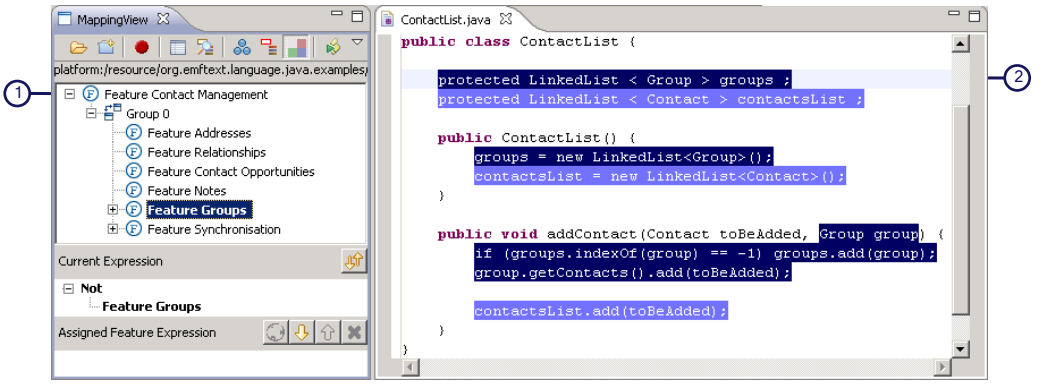
JaMoPP Application: Software Product Line Engineering (FeatureMapper)



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1 – Feature Model

2 – EMFText Editor for Java (code for feature highlighted)

11.4. Integrating DSLs and GPLs (Embedded DSL)

- http://www.jamopp.org/index.php/JaMoPP

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

JaMoPP Applications: What else?

- Round-trip Support for template-based code generators
- Refactoring, Optimization using model transformations
- Traceability-related activities
  - Certification (Map code to the model elements)
  - Impact analysis (How much of the code will change if I do this?)
- Embedded DSL
- Model-based compilation to byte code

- ...

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Using the DSL – Interpretation vs. Compilation

EMFText provides an extension point to perform interpretation (or compilation) whenever DSL documents change

To use the DSL we need to assign meaning by

- **Interpretation**: Traverse the DSL model and perform appropriate actions
- **Compilation**: Translate the DSL constructs to another (possibly executable) language
  - In principle compilation is an interpretation where the appropriate action is to emit code of the target language

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Embedded DSL “Embedded DieSeL”

- An **embedded domain-specific language (embedded DSL)** is a language extension of a general-purpose language (GPL), the base language
- An embedded SDL can be *interpreted* or *reduced (compiled to the core language)*
- Typesafe Template Languages
  - Same syntax as string-based templates

SandwichMaker.java_template

```
1<%TEMPLATE INPUT=
2  "http://www.emftext.org/language/sandwich::Recipe" %>
3
4public class SandwichMaker {
5  private class Instr {};
6  public Instr <%= "instructions" %> = new Instr();
7
8  private boolean cleanIngredients() {}
9  private void addSingleIngredient() {}
10
11  public void addIngredients() {
12    <%FOR "engredients" %> // typo 'ingredients'
13      addSingleIngredient();
14    <%ENDFOR%>
15  }
16
17  public void makeSandwich() {
18    <%IF "instructions->exists(i|i.oclIsKindOf(Clean))" %>
19      boolean success = cleanIngredients();
20    <%ENDIF%>
21
22    if (!success) return; // May not be available
23    addIngredients();
24  }
25}
```

Problems

3 errors, 0 warnings, 0 others

Description	Loc...
Errors (3 items)	
The expression in the placeholder has wrong type (was org.eclipse.ocl.ecore.impl.Order	line 6
The expression "engredients" is invalid (Unrecognized variable: (engredients)).	line 12
ReferenceableElement 'success' not declared	line 22

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Extended Code Generation for a Embedded DSL

- An **Reducer** for an **embedded DSL** is a set of additional code generation rules
  - extending the rule set of the code generation of the base language
- Reducers should be composed modularly with the modules of the base language

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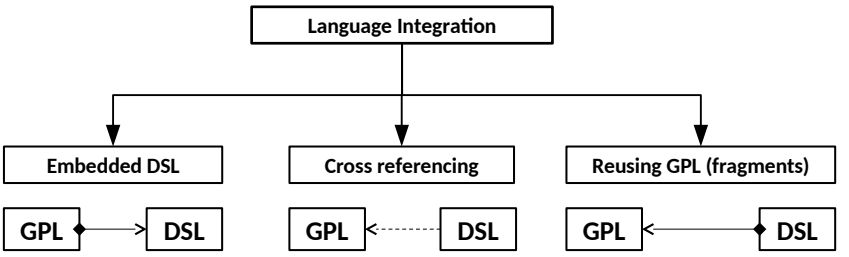
11.4.2 Language Integration by Metamodel and Grammar Inheritance

Integrating DSLs and GPLs

- Different integration scenarios



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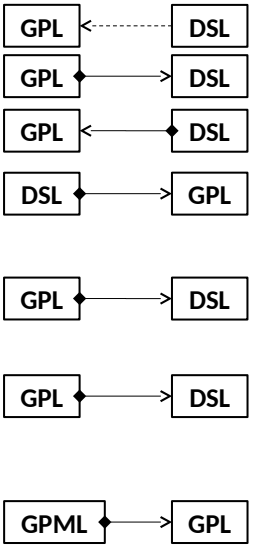
Language Integration Examples

- FormsExtension
- FormsEmbedded
- JavaForms
- eJava
  - Provides metamodels with Eoperations
  - implementations without touching the generated java files
- JavaTemplate
  - Syntax safe templates with JaMoPP
- PropertiesJava
  - Experimental extension for Java to define C# like properties
- JavaBehaviour4UML
  - An integration of JaMoPP and the UML
  - Methods can be directly added to Classes in class diagrams



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Thank you!

Questions?

New URL: https://github.com/DevBoost/EMFText

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