Part III. Technical Spaces
20. Analysis and Model Management in the Technical Space Grammarware and Treeware (Context-Free Syntax Analysis)

Prof. Dr. rer. nat. Uwe Aßmann

Institut für Software- und Multimediatechnik

Lehrstuhl Softwaretechnologie

Fakultät für Informatik

TU Dresden

http://st.inf.tu-dresden.de

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1) Parsing
2) Regular Tree Grammars
3) Tree Construction
4) Text Algebrae
5) Port Graph Algebrae
6) Pseudocode

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Literature

- Obligatory:
  - http://www.antlr.org
- Optional:
  - Cocktail www.cocolab.de, die Compiler-Toolbox für die schnellsten Compiler der Welt (kommerziell, Demoversionen erhältlich)
  - TaTa Tree Grammars http://tata.gforge.inria.fr/ and all the tree theory

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10.1. Parser Generators in the Technical Space Grammarware

- Analyzing the structure of linear lists
- And transforming them to trees

1) Parsing as checker for instance-of
2) Antlr as example
3) Example pocket computer

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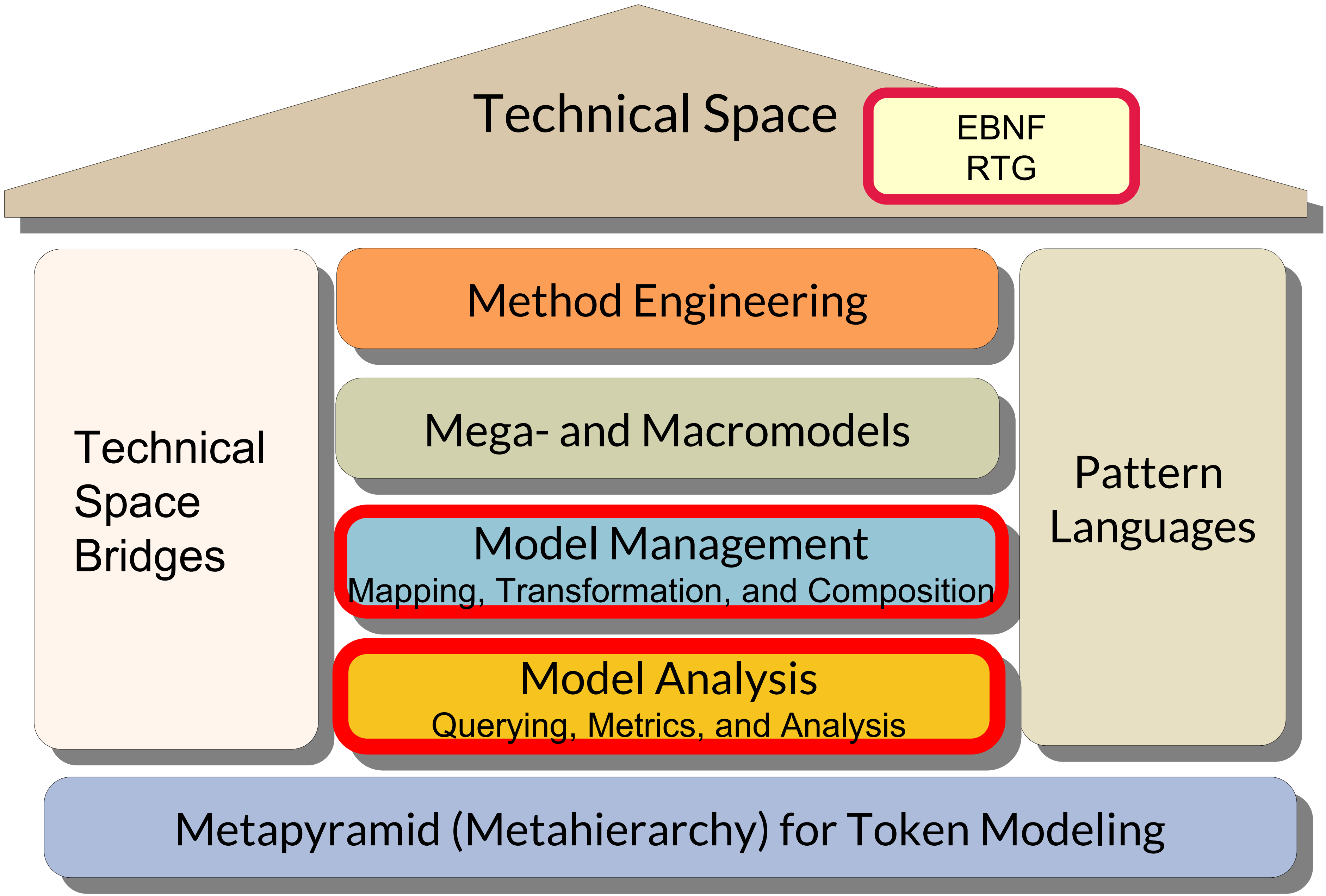
Q10: The House of a Technical Space



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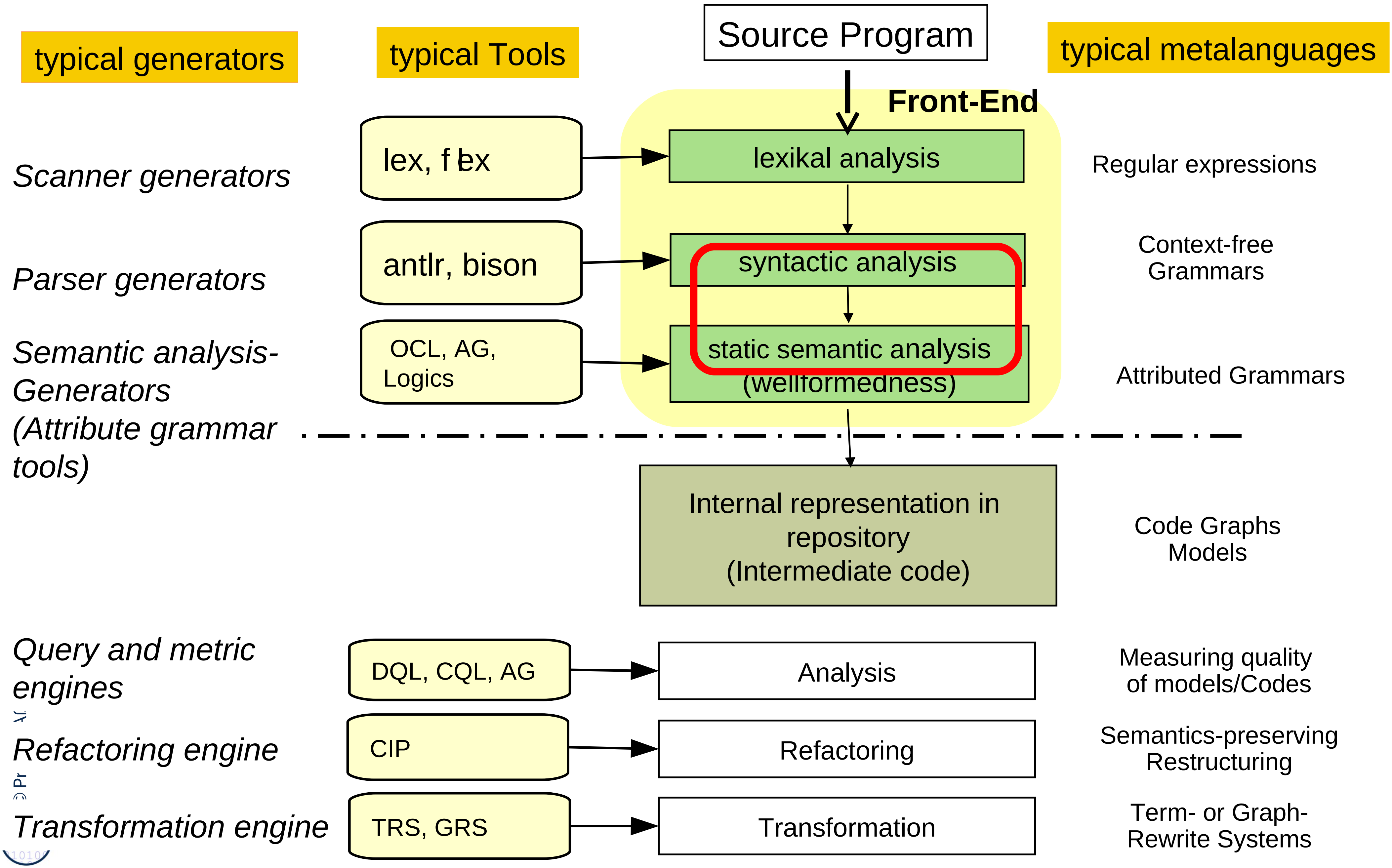
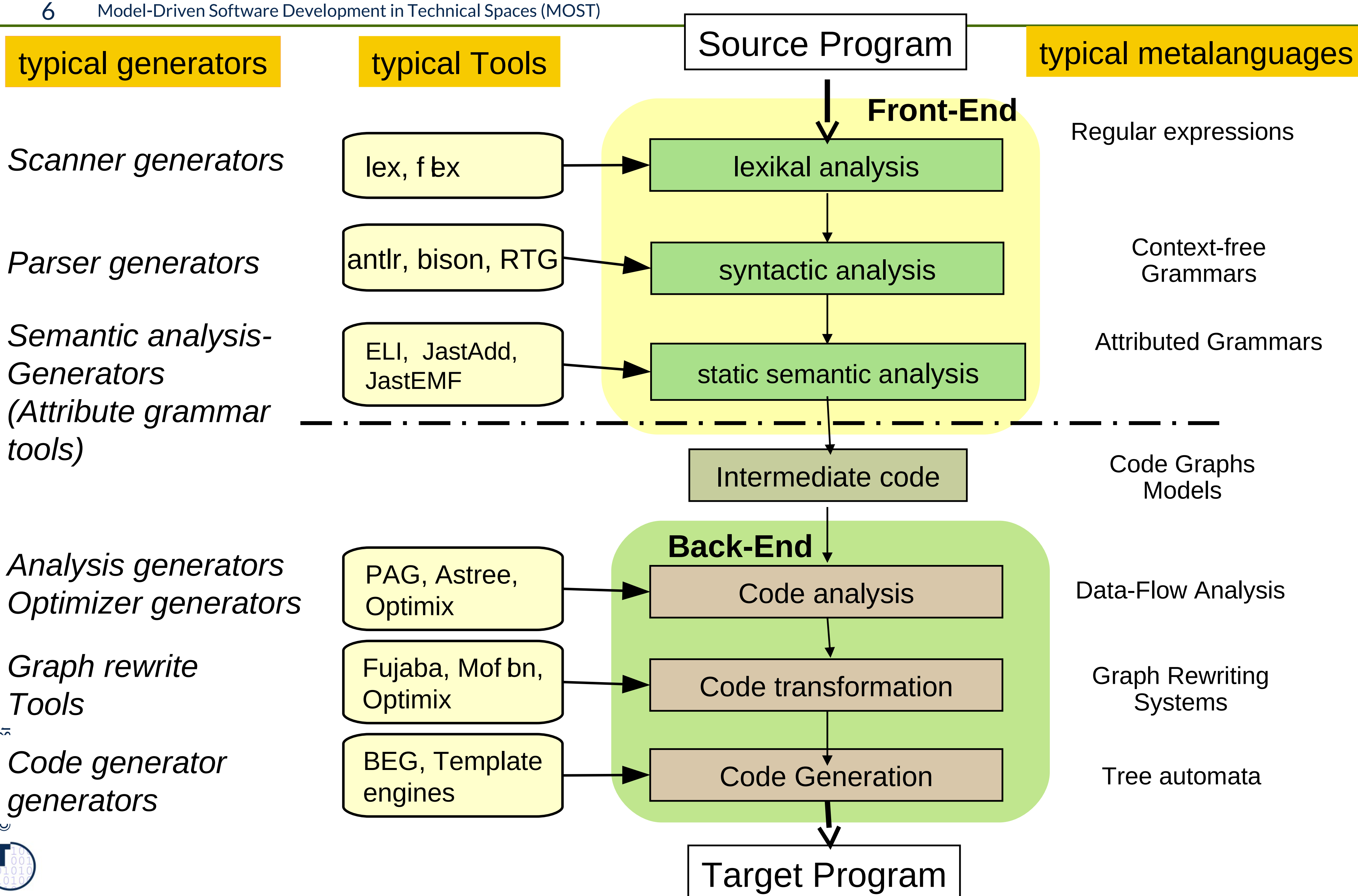
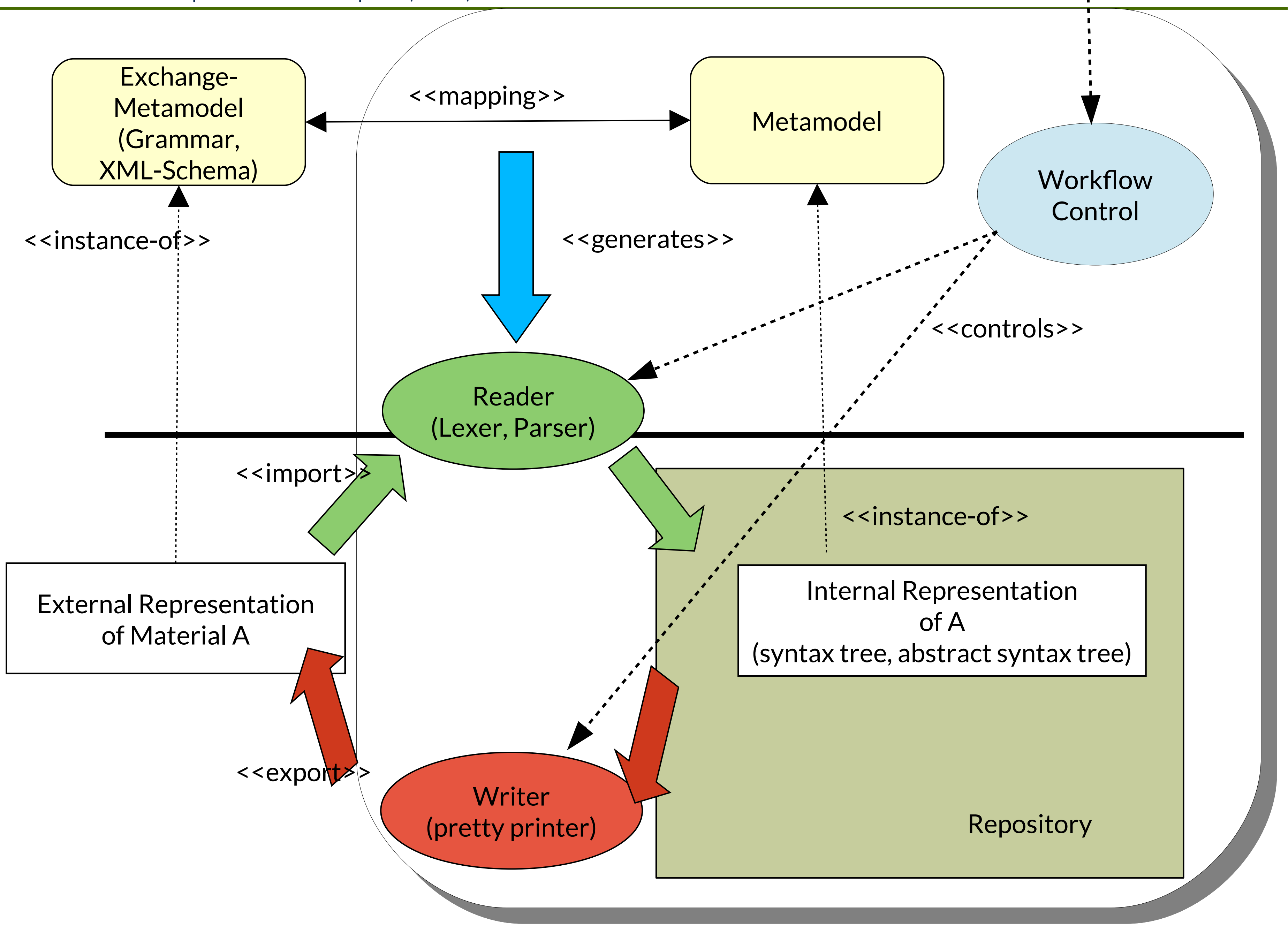
Q7b: Phases of a Source Code Importers into a Repository and the Generating Tools



Q8: Phases of Compilers and Software Tools and Generators



Rpt.: Use of Generated Importers and Exporters in Modelling Tools



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Problem 1 of Parsing

- Parsing a program, model or document, or a material means to **recognize its context-free structure in the linear stream of characters**
  - Parsers are usually the first phases of a tool when it *imports a material*
- Parsers parse according to the *concrete syntax grammar* containing
  - Whitespace handling
  - Block handling (brackets)
  - Comment handling
- From a context-free grammar, a **parse automaton with parse rules** can be derived:
  - Address ::= Streetname StreetNumber Location
  - Location ::= Postcode Town Country
- Generates the parse rules
  - Streetname StreetNumber Location → Address
  - Postcode Town Country → Location
- The parser reads in all tokens until it can decide which rule to reduce

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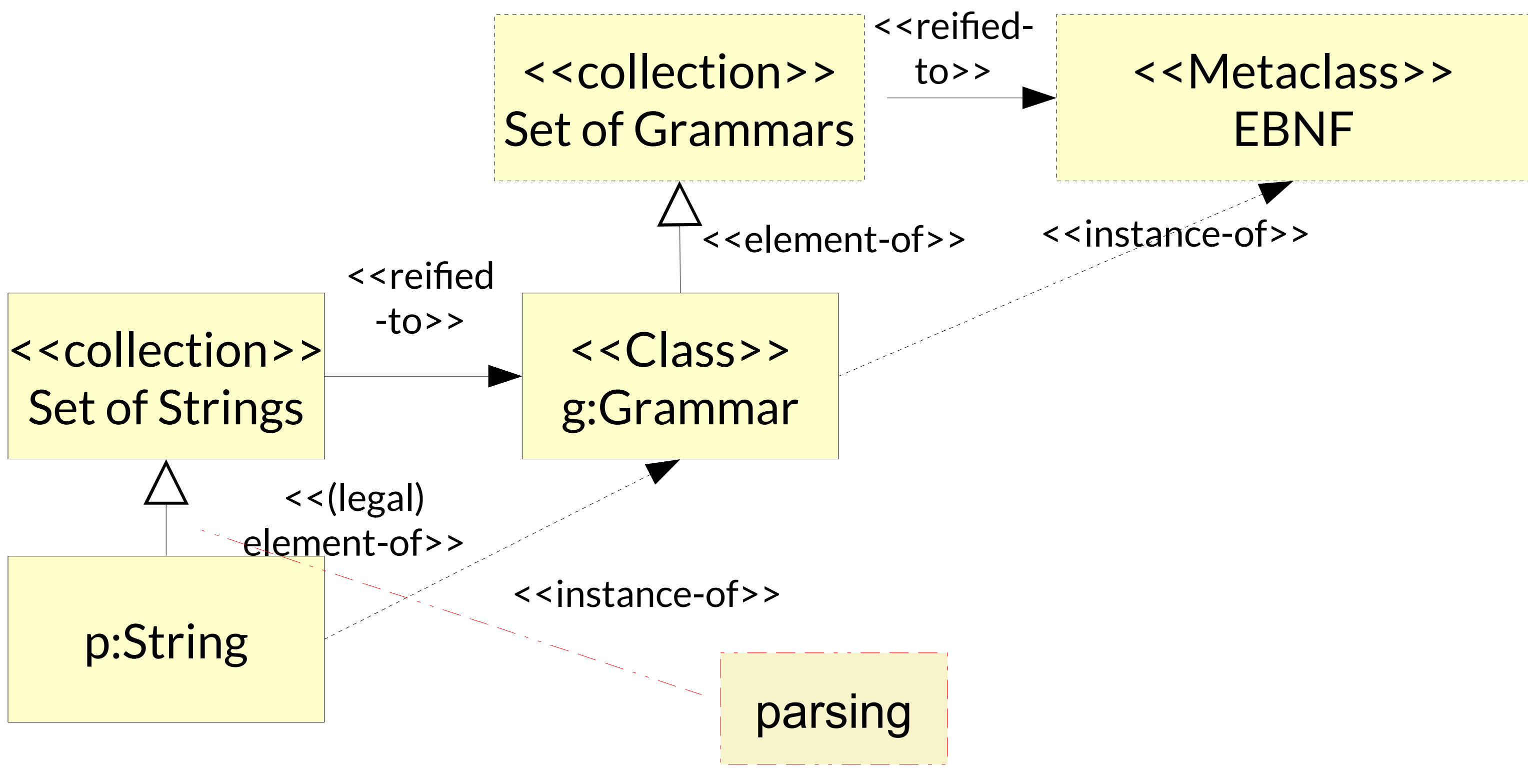
String/Text Parsing with Grammars

- A grammar can be used to generate a parser for strings (texts) that tests the legality of a string with the grammar
- The parser checks <<instance-of>> for the string p with regard to the grammar g



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EBNF Rules for String Grammars

Symbol	Meaning	Example
Name (Nonterminal)	Identifier (for type or variable)	A = B + C
"text"	Token (text terminal)	B ::= "Town" + R
=, ::=	Consists of	X ::= X1 + X2 + X3
+, also juxtaposition	Sequence	X ::= X1 X2 X3
@	Key (unique identifier)	P = @PersonNr + N + Address
[...|...]	Selection (alternative)	P = [P1 | P2]
n { ... } m	Iteration, at least n upto m times	B = 1 { C } 10
n *	Iteration of n - arbitrarily many times	Children ::= Name *
n +	Iteration of n at least once	PastEmployers ::= Name +
(...)	Optional	Address ::= Street + (PostBox)
A // “,”	Sequence of A with intermittend ','	C = D // “,”
* ... *	Comment	X = B + C *text*
< a > b	Modifier (Kommentar)	< old > A < new > A
SYN	Synonym für Name	SecondName SYN SurName

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Example: Address Grammar

- "::=" means "is-composed-of" or "is-decomposed-to"
- Every rule declares a whole-part decomposition
- Grammar declares the structure of a part list

```
Address ::= Person Company Location.
Person ::= Title Name
Title ::= „Dr.“ | „Prof. Dr.“ | „Mr.“ | „Ms.“
Name ::= FirstName* LastName
Company ::= String
Location ::= Street StreetNumber Postcode Town
FirstName ::= String
LastName ::= String
Postcode ::= 5{Digit}5
Street ::= String
StreetNumber ::= Integer [ String ]
Town ::= String
```

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Example: ANTLR www.antlr.org

- Since the 90s, many parser generators have been built for C/C++
    - Cocktail's lalr, ell, lark www.cocolab.de
    - Fnc2 (INRIA)
    - flex und bison (GNU)
    - Eli is a fast compiler generator toolset http://eli.sf.net
- For Java, ANTLR is popular
    - Parser class LL(k): Left-recursive grammar rules, k-lookahead for decisions
    - Generated Parser with algorithm "recursive descent"
    - http://www.bearcave.com/software/antlr/antlr_expr.html

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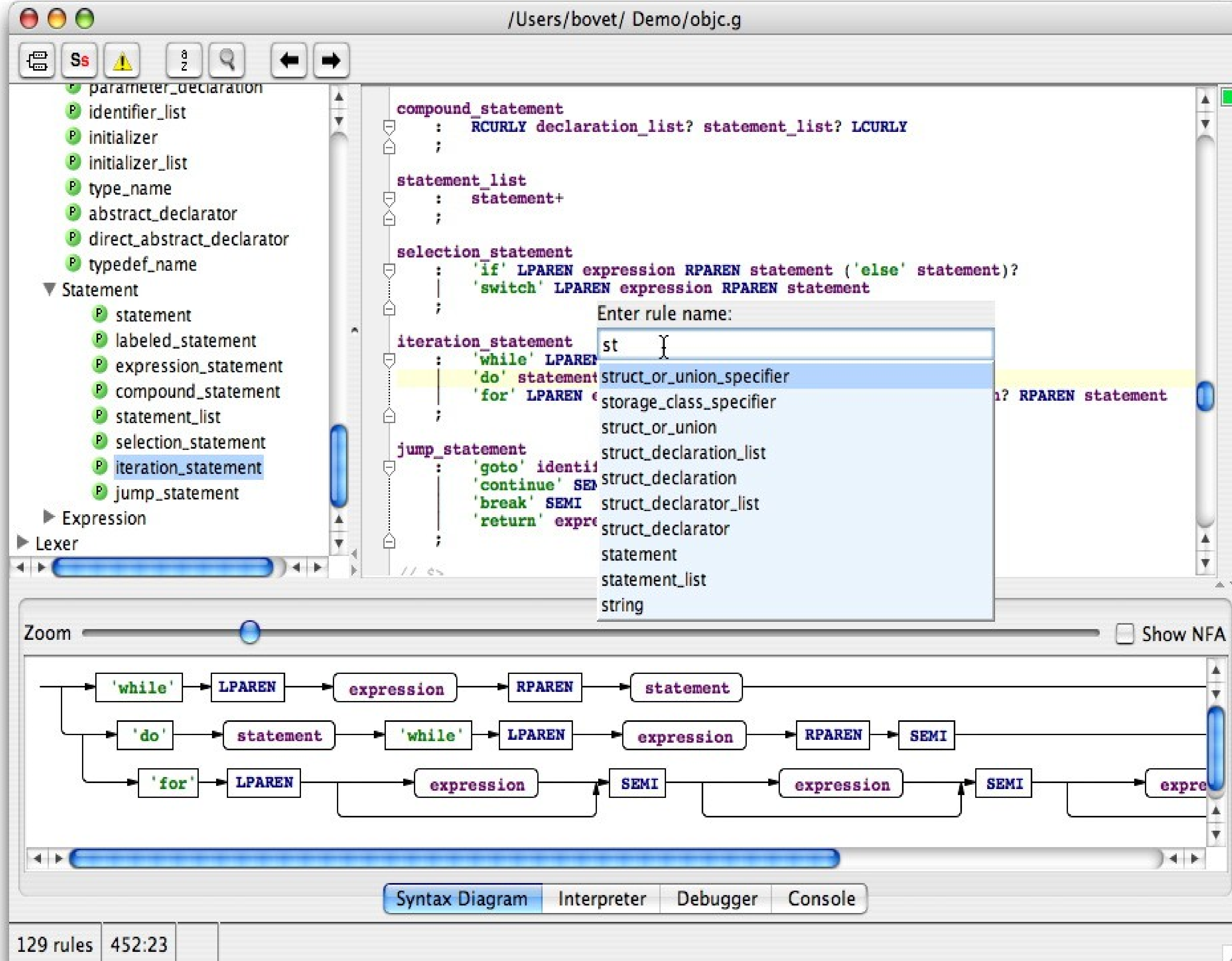

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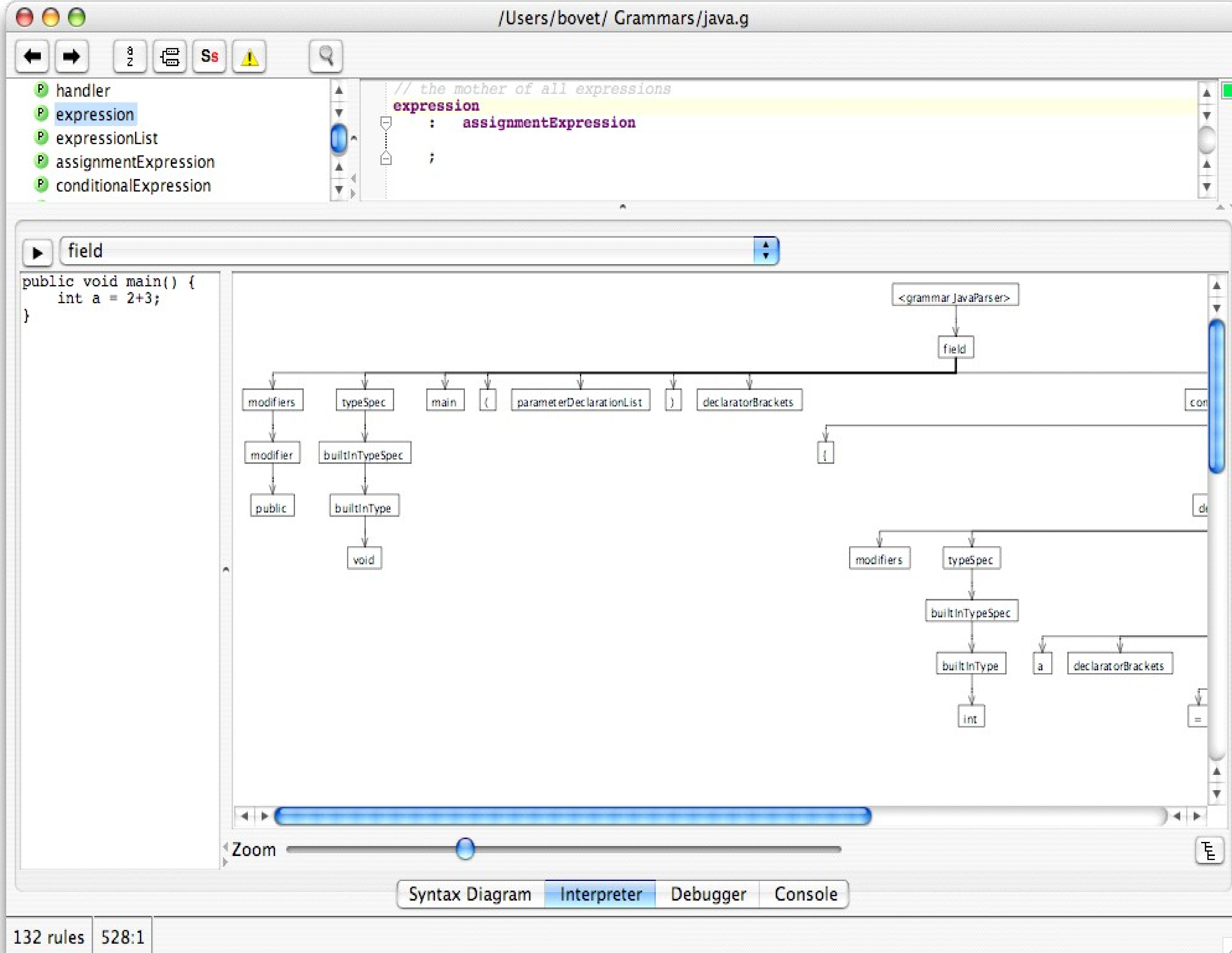
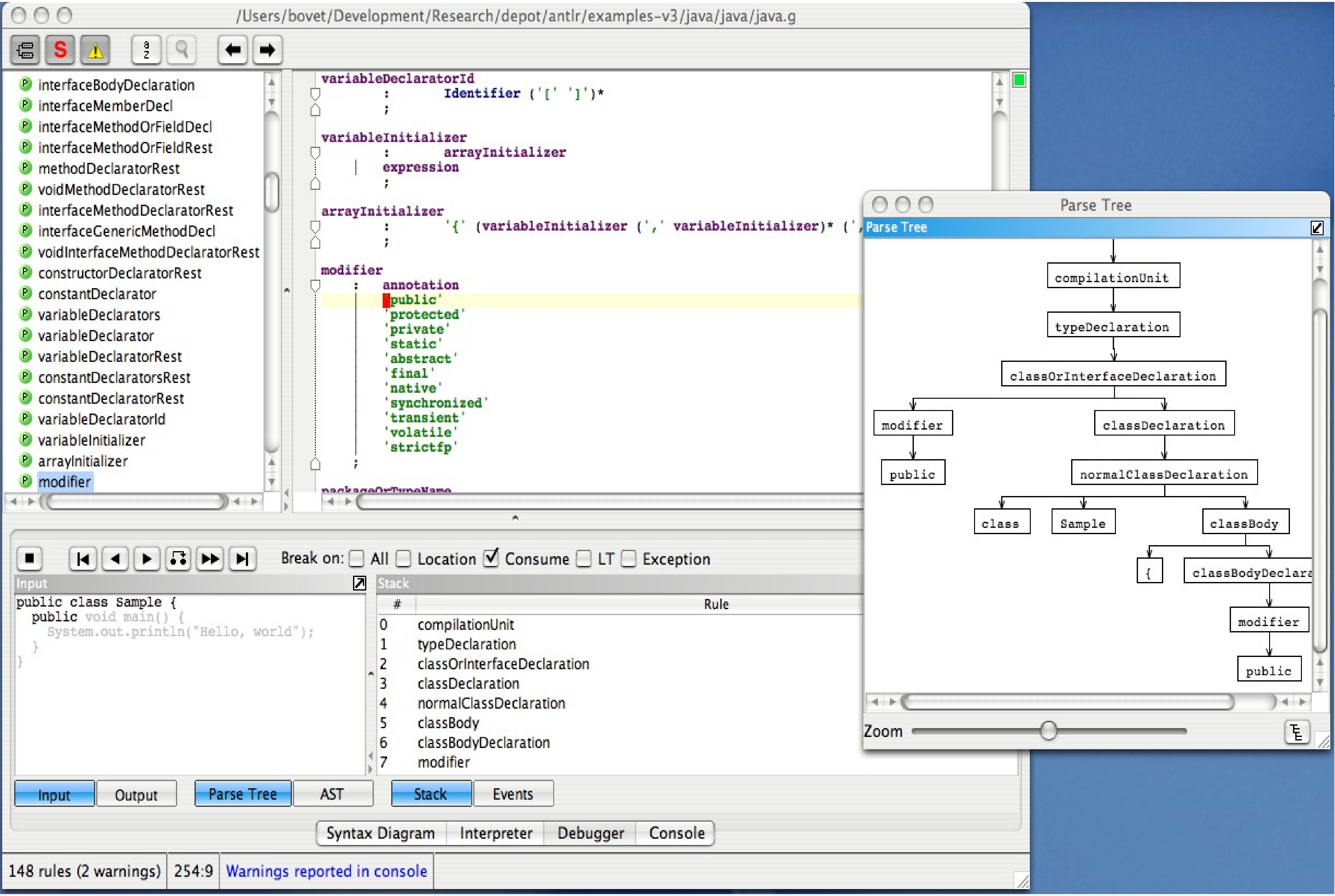
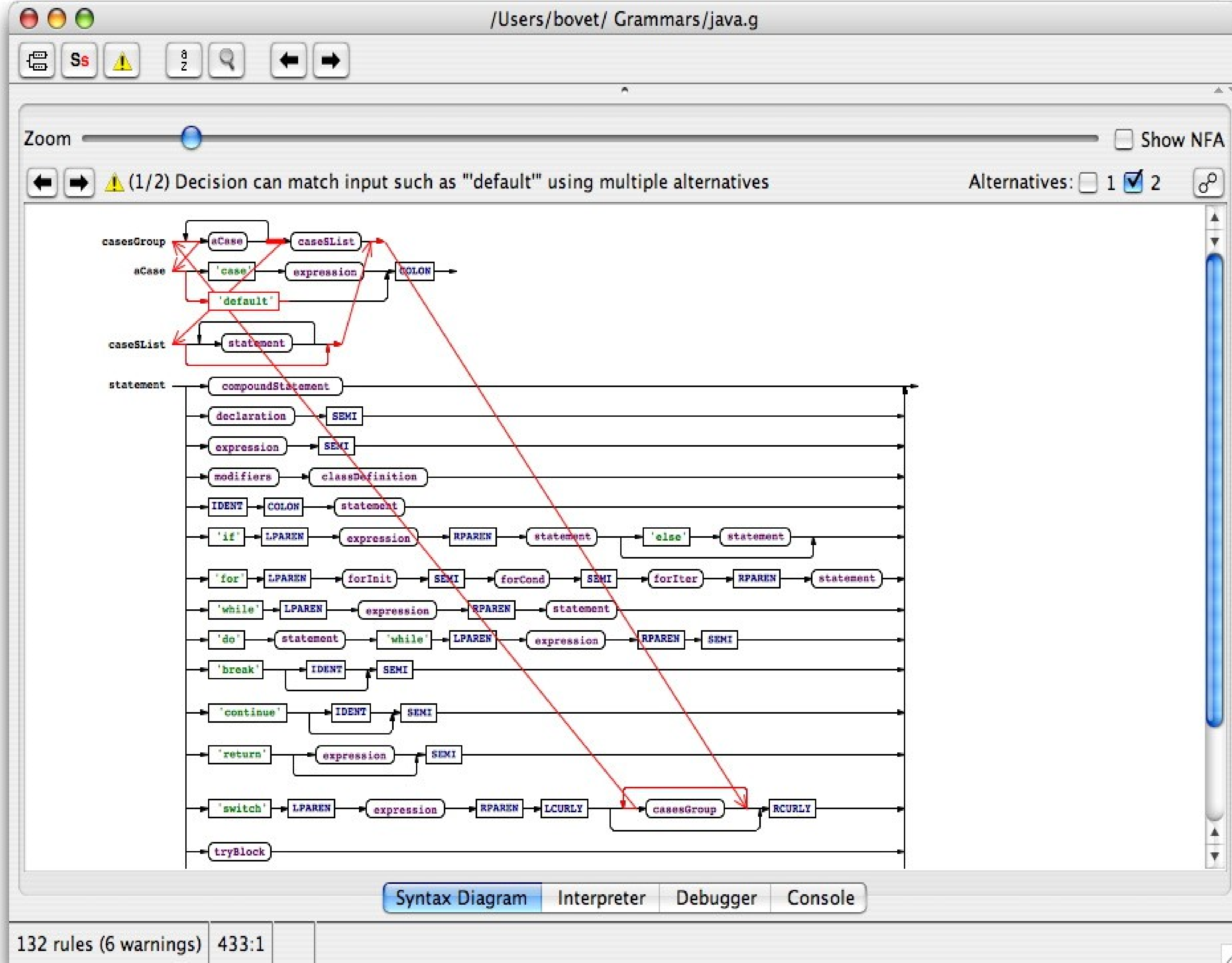

/Users/bovet/ Grammars/java.g
handler
expression
expressionList
assignmentExpression
conditionalExpression
// the mother of all expressions
expression
: assignmentExpression
;
field
public void main() {
int a = 2+3;
}
<grammar JavaParser>
field
modifiers
typeSpec
main
(
parameterDeclarationList
)
declaratorBrackets
modifier
builtInTypeSpec
{
public
builtInType
void
modifiers
typeSpec
builtInTypeSpec
builtInType
a
declaratorBrackets
int
=
Zoom
Syntax Diagram
Interpreter
Debugger
Console
132 rules
528:1


/Users/bovet/Development/Research/depot/antlr/examples-v3/java/java.g
interfaceBodyDeclaration
interfaceMemberDecl
interfaceMethodOrFieldDecl
interfaceMethodOrFieldRest
methodDeclaratorRest
voidMethodDeclaratorRest
interfaceMethodDeclaratorRest
interfaceGenericMethodDecl
voidInterfaceMethodDeclaratorRest
constructorDeclaratorRest
constantDeclarator
variableDeclarators
variableDeclarator
variableDeclaratorRest
constantDeclaratorsRest
constantDeclaratorRest
variableDeclaratorId
variableInitializer
arrayInitializer
modifier
variableDeclaratorId
: Identifier ('[' ']')*
;
variableInitializer
: arrayInitializer
| expression
;
arrayInitializer
: '{' (variableInitializer (',' variableInitializer)* (',
;
modifier
: annotation
'public'
'protected'
'private'
'static'
'abstract'
'final'
'native'
'synchronized'
'transient'
'volatile'
'strictfp'
;
Parse Tree
Parse Tree
compilationUnit
typeDeclaration
classOrInterfaceDeclaration
modifier
classDeclaration
public
normalClassDeclaration
class
Sample
classBody
{
classBodyDeclara
modifier
public
Zoom
Break on: All Location Consume LT Exception
Input
public class Sample {
public void main() {
System.out.println("Hello, world");
}
}
Stack
Rule
0 compilationUnit
1 typeDeclaration
2 classOrInterfaceDeclaration
3 classDeclaration
4 normalClassDeclaration
5 classBody
6 classBodyDeclaration
7 modifier
Input
Output
Parse Tree
AST
Stack
Events
Syntax Diagram
Interpreter
Debugger
Console
148 rules (2 warnings)
254:9
Warnings reported in console



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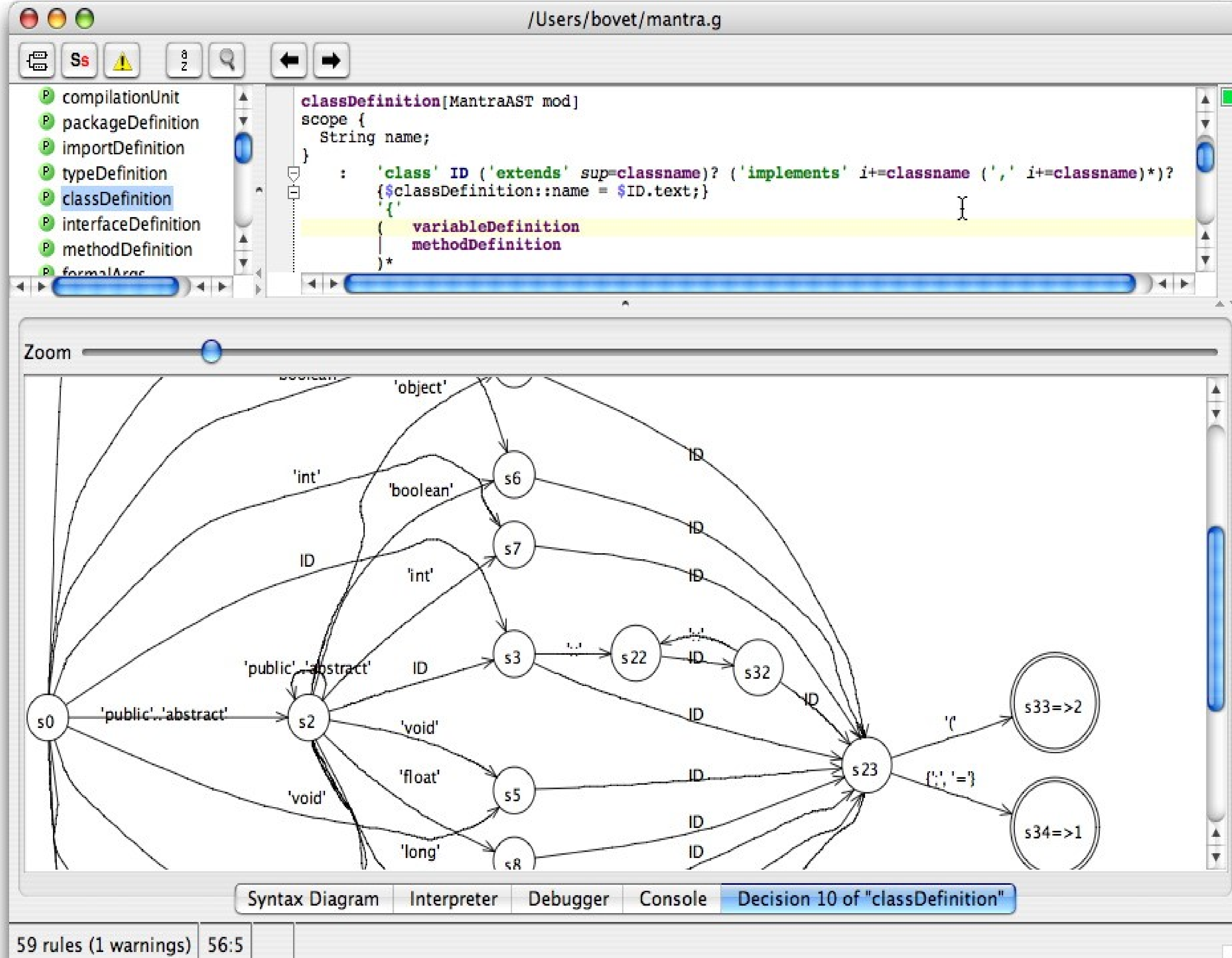

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10.1.2 An ANTLR Grammar for the Input Language of Pocket Calculator

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- Pocket calculator interpretes mthe program to calculate one attribute
  - Interpretation needs non-terminal attributes
- Usually, the parse automaton with the parse rules is not shown, because it is rather complex
- Debugging a generated parser is no fun

```
grammar Expr;
@header {
package test;
import java.util.HashMap;
}
@lexer::header {package test;}
@members {
/** Map variable name to Integer object holding value */
HashMap memory = new HashMap();
}
prog:   stat+ ;

stat:   expr NEWLINE {System.out.println($expr.value);}
    |   ID '=' expr NEWLINE
        {memory.put($ID.text, new Integer($expr.value));}
    |   NEWLINE
    ;
expr returns [int value]
    :   e=multExpr {$value = $e.value;}
        (   '+' e=multExpr {$value += $e.value;}
        |   '-' e=multExpr {$value -= $e.value;}
        )*
    ;
multExpr returns [int value]
    :   e=atom {$value = $e.value;} ('*' e=atom {$value *=
$e.value;})*
    ;
atom returns [int value]
    :   INT {$value = Integer.parseInt($INT.text);}
    |   ID
        {
        Integer v = (Integer)memory.get($ID.text);
        if ( v!=null ) $value = v.intValue();
        else System.err.println("undefined variable "+$ID.text);
        }
    |   '(' e=expr ')' {$value = $e.value;}
    ;
// lexical rules
ID  :   ('a'..'z'|'A'..'Z')+ ;
INT :   '0'..'9'+ ;
NEWLINE:'\r'? '\n' ;
WS  :   (' '|'\t')+ {skip();} ;
```

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Control of a Generated Java Parser


```
import org.antlr.runtime.*;
public class Test {
    public static void main(String[] args) throws Exception {
        ANTLRInputStream input = new ANTLRInputStream(System.in);
        ExprLexer lexer = new ExprLexer(input);
        CommonTokenStream tokens = new CommonTokenStream(lexer);
        ExprParser parser = new ExprParser(tokens);
        parser.prog();
    }
}
```

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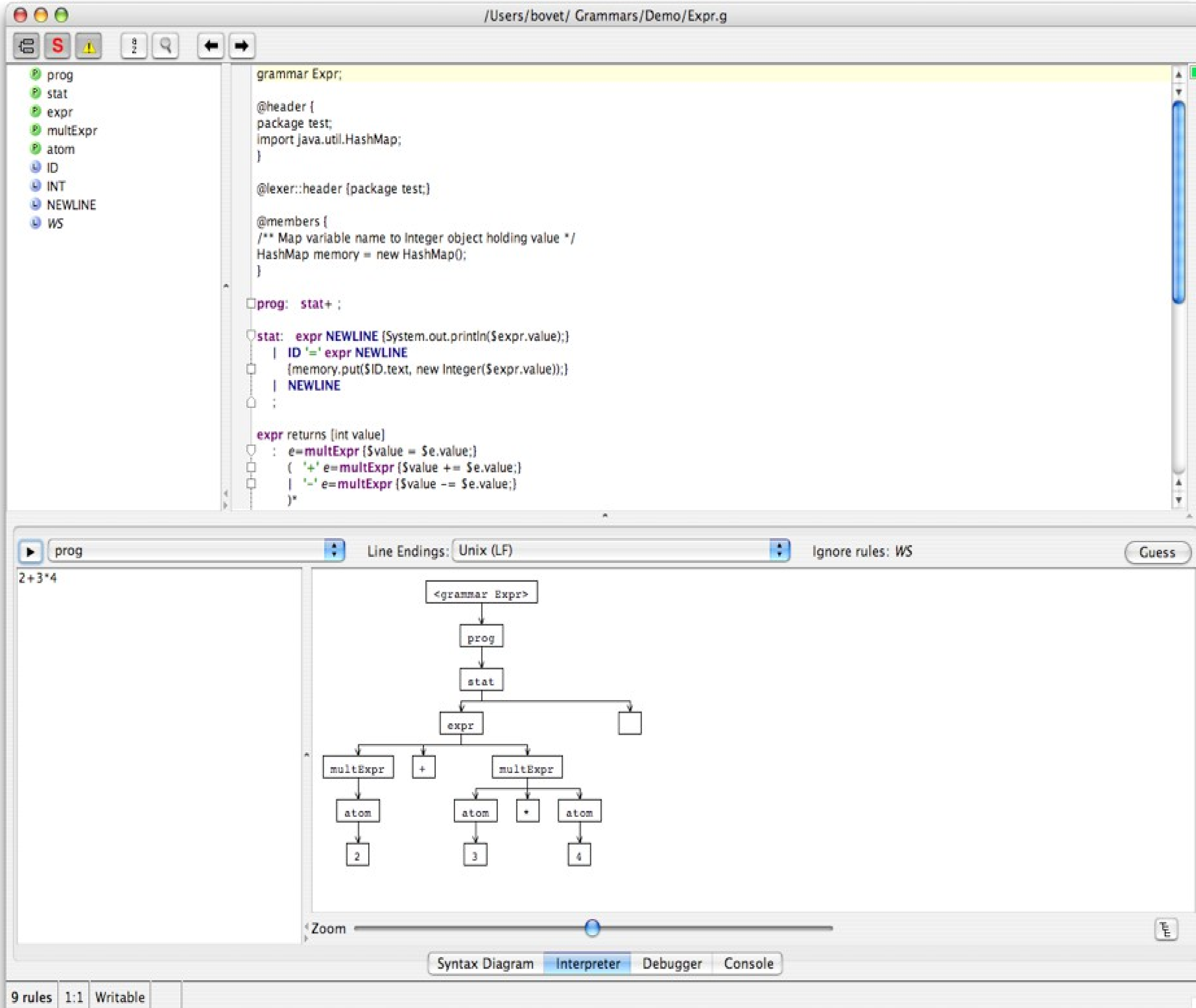

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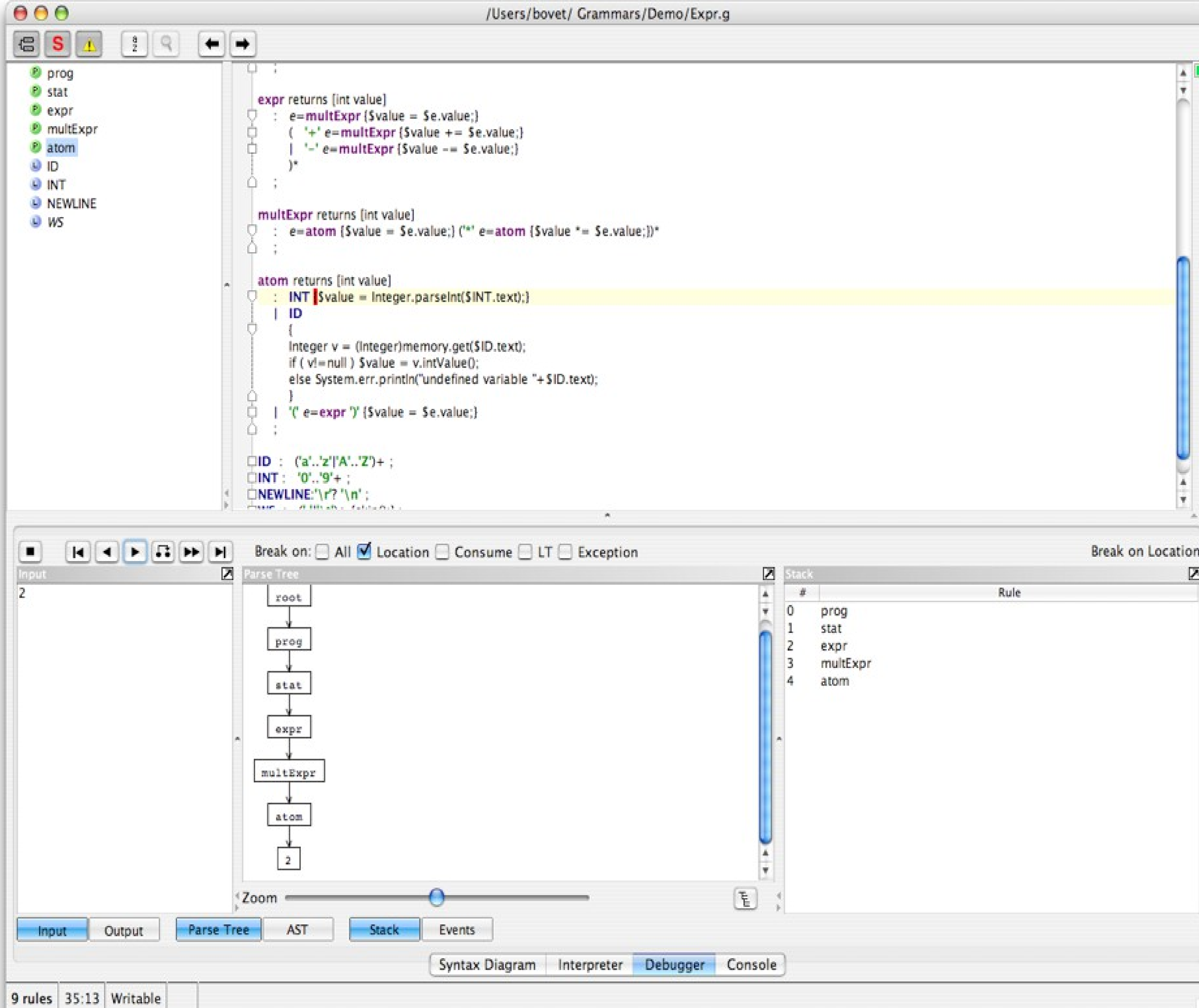

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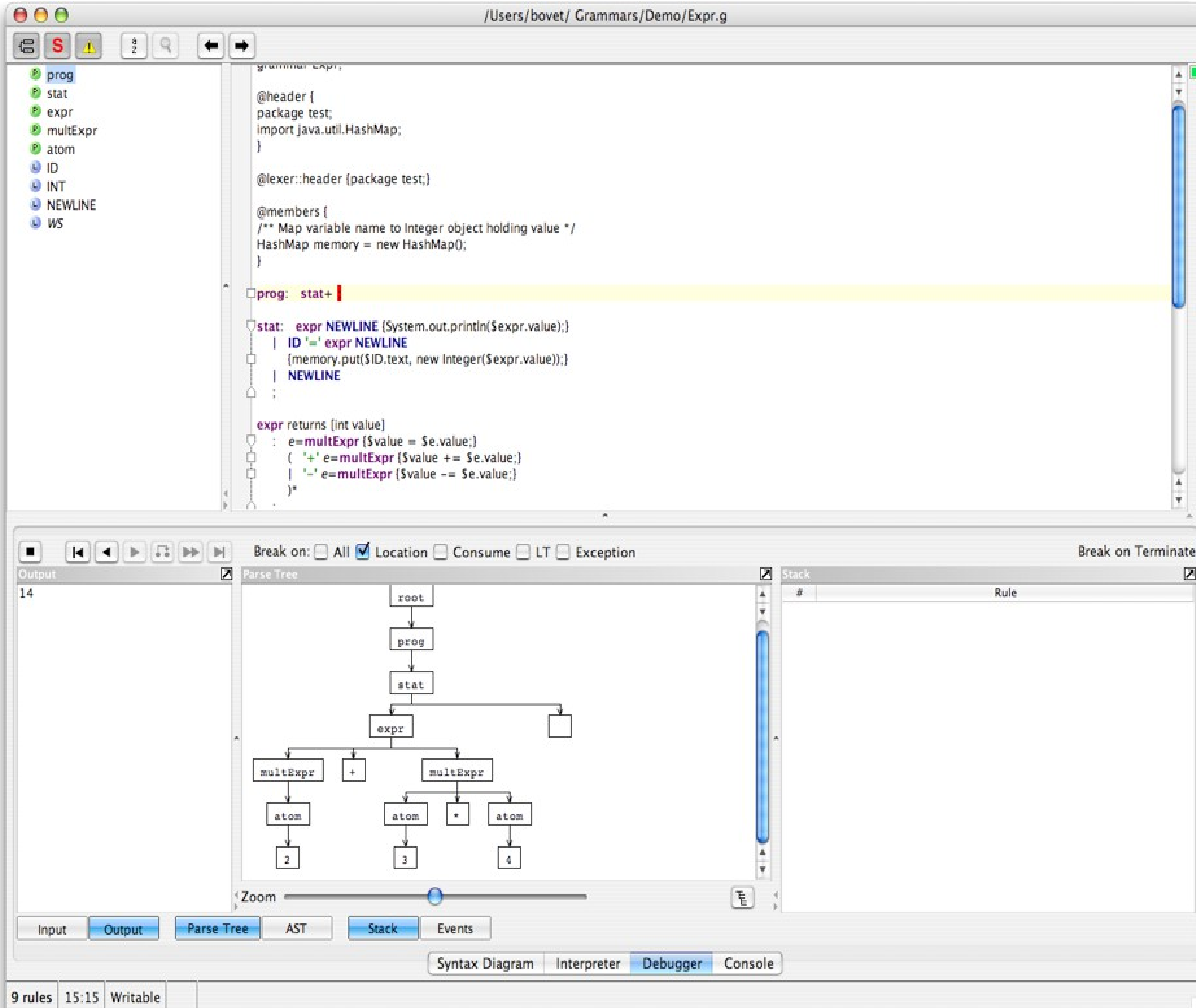

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Applications of String Grammars

Everything that has to do with *ordered strings*:

- Protocol checking in component-based systems (protocol automata and grammars)
- Document processing
- Matching text patterns and data mining in files, emails, streams
- Communication in multi-agent systems

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10.2 Regular Tree Grammars

- String grammars are for structuring sequences
- RTG are for specifying trees, syntax trees and abstract syntax trees
- A RTG does not care about concrete syntax

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Regular Tree Grammars

http://hydra.nixos.org/build/23332578/download/1/manual/chunk-chapter/demo-sdf.html#idm140737305321888

- String Grammars assume:
  - Sequence of words
  - Implicit syntax tree, because non-terminals specify it implicitly
- Regular Tree Grammars specify the tree directly, with tree node constructors
- ENBF-rule for Tree Grammar Rule:

TreeNode constructor '(' Treenode // ',' ')'

- Example:

Model ModelElements *

```
// Regular Tree Grammar from Stratego
regular tree grammar TIL
 start Program
 productions
  Program     -> Program(ListStarOfStat0)
  Stat        -> ProcCall(Id,ListStarOfExp0)
  Exp         -> FunCall(Id,ListStarOfExp0)
  Stat        -> For(Id,Exp,Exp,ListStarOfStat0)
  Stat        -> While(Exp,ListStarOfStat0)
  Stat        -> IfElse(Exp,ListStarOfStat0,ListStarOfStat0)
  Stat        -> IfThen(Exp,ListStarOfStat0)
  Stat        -> Block(ListStarOfStat0)
  Stat        -> Assign(Id,Exp)
  Stat        -> DeclarationTyped(Id,Type)
  Stat        -> Declaration(Id)
  Type        -> TypeName(Id)
  Exp         -> Or(Exp,Exp) | And(Exp,Exp)
  Exp         -> Geq(Exp,Exp)  | Eq(Exp,Exp) | Neq(Exp,Exp)
  Exp         -> Gt(Exp,Exp)   | Lt(Exp,Exp) | Leq(Exp,Exp)
  Exp         -> Sub(Exp,Exp)  | Add(Exp,Exp)
  Exp         -> Mod(Exp,Exp) | Div(Exp,Exp) | Mul(Exp,Exp)
  Exp         -> String(String)
  Exp         -> Int(Int) | Var(Id)
  Exp         -> False() | True()
  StrChar     -> <string>
  String      -> <string>
  Int         -> <string>
  Id          -> <string>
```

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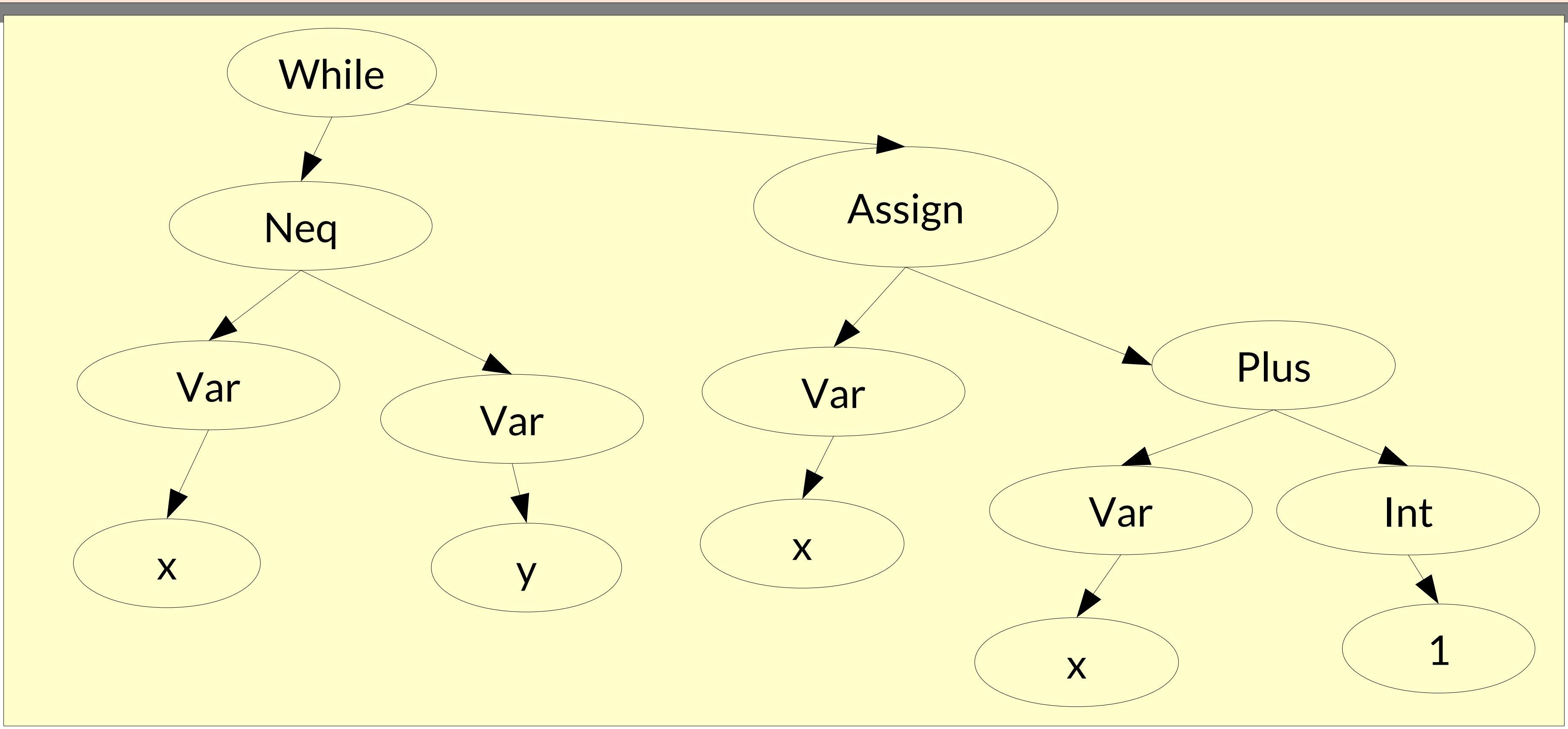
Correct Model?

```
// Example: applying TIL grammar to a fragment
ExecuteGrammar(TIL,
    While(Neq(Var(x),Var(y)), Assign(Var(x),Plus(Var(x),Int(1) ) )
)
```



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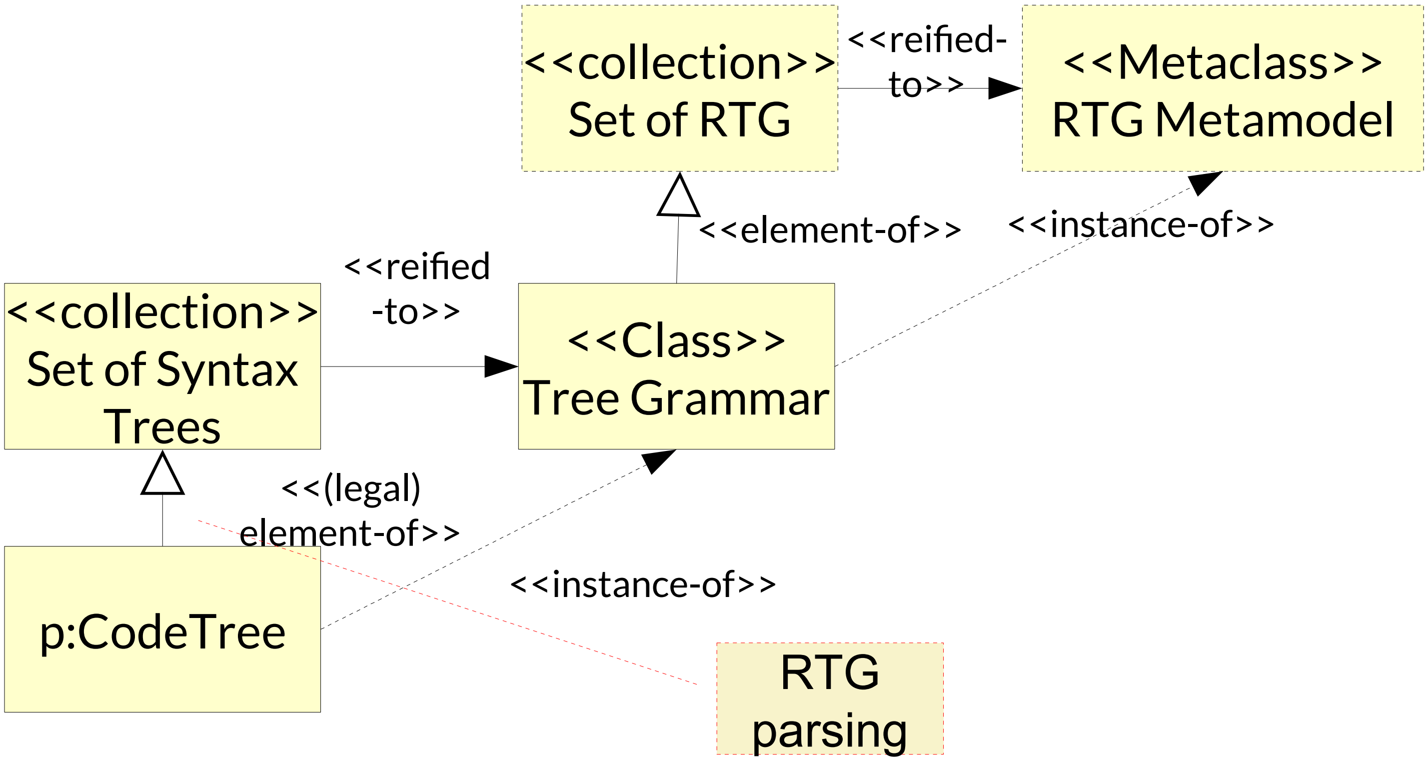
Tree Parsing with RTG

- An RTG can be used to generate a **tree parser** that tests the legality of a code tree with a tree grammar



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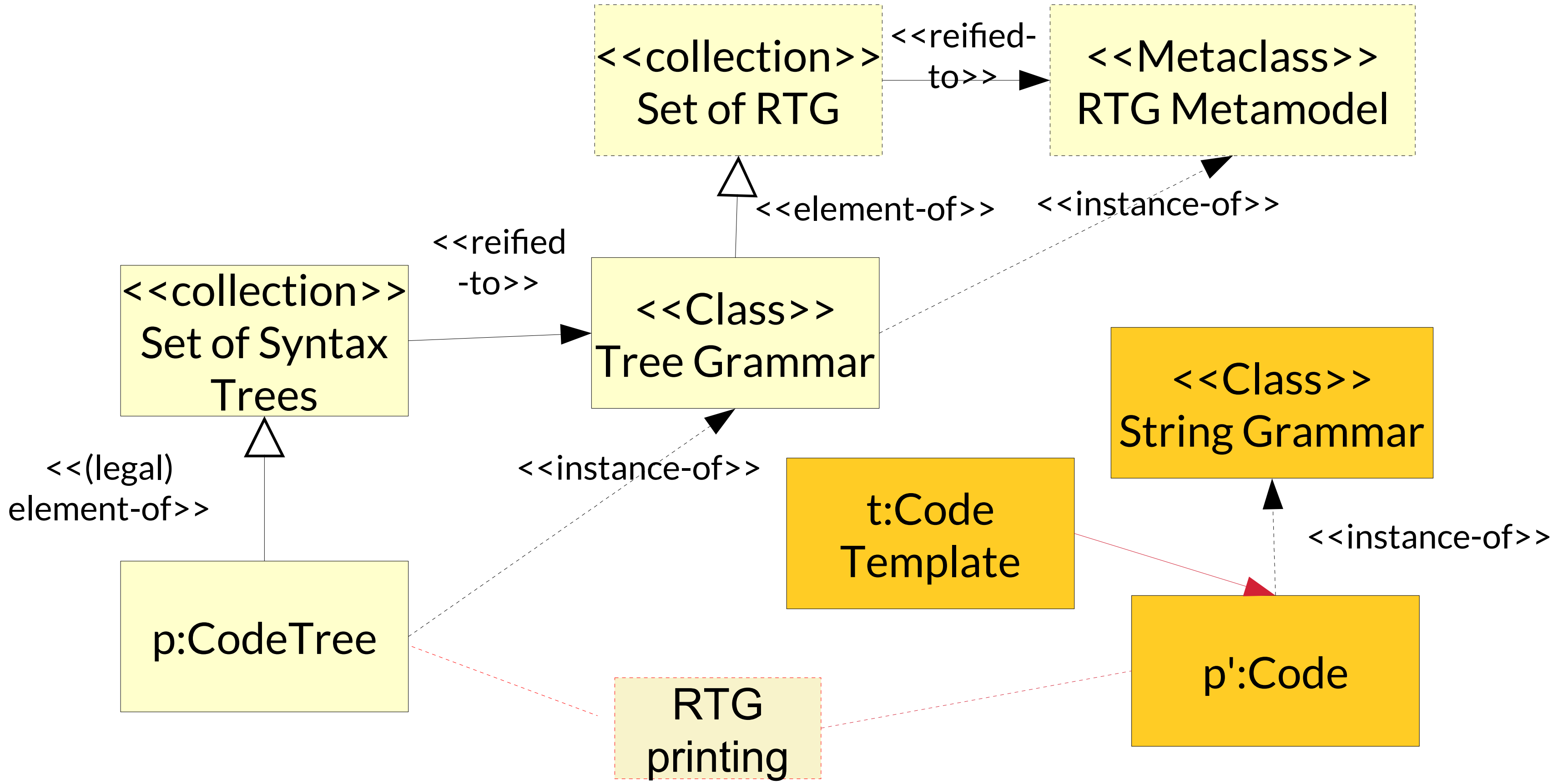
Tree Pretty-Printing with RTG

- An RTG can be used to generate a **tree pretty-printer** that prints the nodes of a tree recursively
- If p is a code tree, p' can be its pretty-printed copy, derived of a code template t
- Exercise: write a pretty-printer for the RTG TIL



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10.3. Tree Construction as a Mapping between Parse Grammar and Tree Grammar

- Foll parser also build syntax trees – Design Pattern Builder

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Tree Construction While Parsing

- Parsing recognizes the tree structure of a text – **however, the syntax tree must be built**
- After parsing, the parser creates an **(abstract)** *syntax tree*, i.e., builds up a tree with regard to a ***regular tree grammar of the abstract syntax***
  - Recognized nonterminals have to be mapped
  - Tokens, keywords, comments, layouts have to be omitted
  - **Tree building:** Treenodes have to be allocated
- This **CS-AS mapping (from concrete to abstract syntax)** is created by hand in *side actions* of the parser
- For simple languages, parsers and tree constructors are no longer written by hand, but generated from *grammars in EBNF*
  - **Parser** recognizes the structure of the text ("Zerteiler des Textes")
  - **Tree builder** generates an abstract syntax tree
  - **CS-AS-mapping** creates AS nodes after recognition of CS nonterminals

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Constructing a Tree Grammar fitting to the String Grammar of Office DSL


```
//*******************************************************************************
// 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
// ******************************************************************************/
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:Element* "}" ;

    Elements ::= Office | Employee;
    Office ::= "office" name[];

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

.CS Grammar Plus Mapping to RTG (Abstract Syntax Tree)

- CS-AS mapping works via side actions of the grammar rules
- Tree is built while returning from recursive descent

```
//*******************************************************
// Copyright (c) 2006-2015 under EPL
// Software Technology Group, Dresden University of Technology
// http://www.eclipse.org/legal/epl-v10.html
//
//******************************************************/
SYNTAXDEF office  FOR <http://emftext.org/office>
TREENODES { // RTG
      START NodeOfficeModel
      NodeOfficeModel →
NodeOfficeModel(name:String,elements:Element *)
      Element → Office(name:String) |
                Employee(name:String, worksIn:String,
worksWith:String *)
}
START OfficeModel
RULES {
    OfficeModel returns [NodeOfficeModel root]
      ::= "officemodel" name[] "{" elements:Element * "}"
    {  root = NodeOfficeModel()
       root.name = name; root.elements = assemble elements; };
    Elements returns [Element retval]
      ::= Office  { retval = Office.val;  }
      | Employee  { retval = Employee.val;  };
    Office returns [Element retval]
      ::= "office" name[] { retval = Office(name);  };
    Employee returns [Element retval]
      ::= "employee" name[] "works" "in" worksIn[]
                                 "works" "with"
                                 worksWith[] ("," worksWith[])*
    { retval = Employee(name,worksIn,assemble worksWith);
    };
}
```

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Modeling Tools need Several Languages and DSL

- Bidirektional mapping between technical space “Grammarware” and another one, e.g., “Treeware”, “Link-TreeWare”, “XMLWare”, or “Modelware”

> How can an MDSD Tool work flexibly with several *textual* languages?

> Generating parsers and tree builders from string grammars and RTG
>
> … and generate from the RTG ..
>
> Pretty printers (Code generators)

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Example: EMFText: EMOF and RTG

- EMFText uses the parser generator ANTLR to generate parsers
- The EMOF metamodels have a primary tree that can be written down as RTG
- Mapping concrete to abstracte syntax:
  - EBNF Grammar and the (implicit) RTG of the corresponding EMF metamodel are mapped *automatically* to each other (language mapping)
- For pretty printer generation, EMFText uses template-based code generation for the (implicit) RTG

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10.4 Text Algebrae

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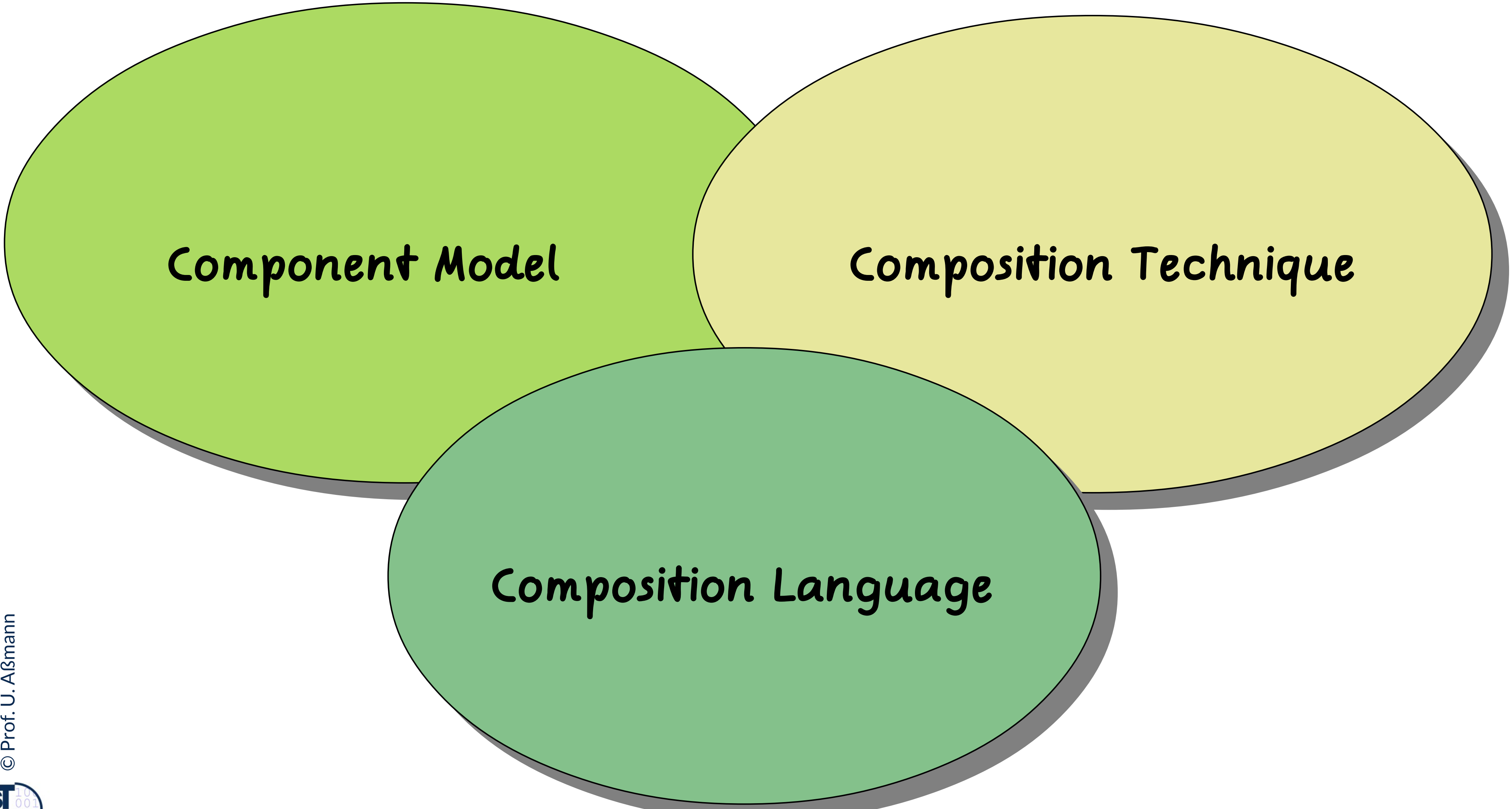
Composition with Composition Systems



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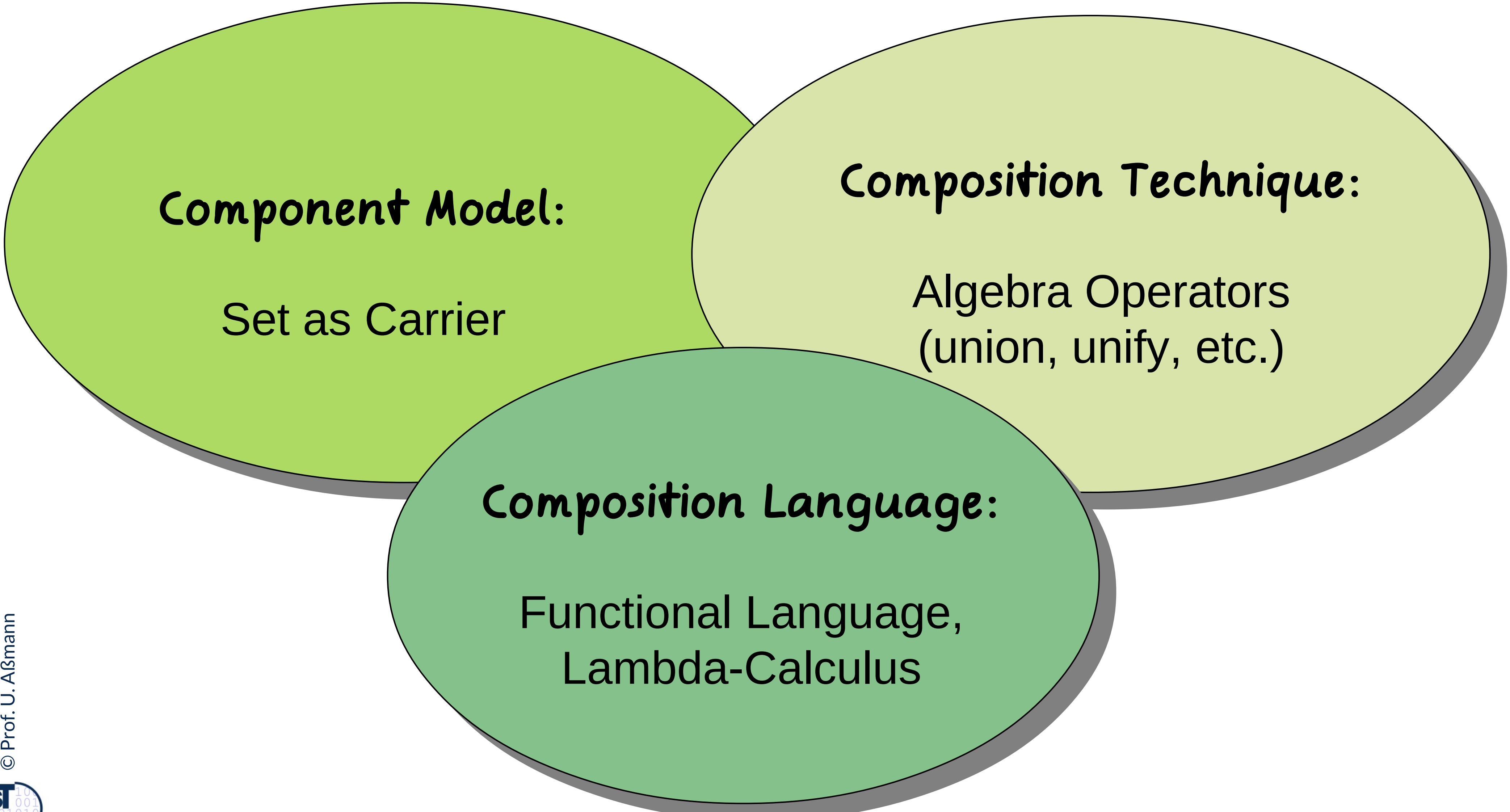
Composition with Algebrae in Mathematics



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One-sorted Algebra on Texts

- A **one-sorted algebra** is a set of operators on a carrier set (Trägermenge) of a type (a sort)
- Example: Texts, sequences of lines of characters
- The parser parses texts into lines, separated by newline characters
- The UNIX Programmers Workbench is built on an algebra on texts:
  - diff: Text x Text edit-sequence (for a transformation)
  - cmp: Text x Text Boolean
  - patch: Text x edit-sequence Text
  - diff3: mine:Text x older:Text x yours:Text edit-sequence
  - split: Text x Split-char Text*
  - match/grep: Text x Pattern Text*
  - check-property: Text x Pattern Boolean
  - is-consistent: Text x Text Boolean
  - format: Text Text
  - expand: Text-template x Text* Text

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CSV: A One-Sorted Algebra on Ascii-Tables

- Tables consist of sequences of lines, split into columns by a column-separator (TAB , COMMA, |)
  - .csv-tables (comma separated values)
  - html-tables, tex-tables
- `rdb` is a command tool suite on an algebra on tables:
  - `Diff:    table x table    edit-sequence`
  - `Cmp:     File x File    Boolean`
  - `Patch:   table x edit-sequence    table`
  - `Diff3:   mine:table x older:table x yours:table    edit-sequence`
  - `split:   table x Splitzeichen    table*`
  - `match:   table x Pattern    table*`
  - `check-property: table x Pattern    Boolean`
  - `is-consistent: table x table    Boolean`
  - `join, sort, group-by...`
  - `format: table    table`
  - `expand: table-template x table*    table`

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10.5 Port-Graph Algebrae on Fragments

Invasive Software Composition is a general, typed templating technique for all languages

... based on port-graph algebrae

... with Graybox Components

... preview onto the summer (CBSE course)

Oana Andrei, Helene Kirchner. A Port Graph Calculus for Autonomic Computing and Invariant Verification. A. Corradini. TERMGRAPH 2009, 5th International Workshop on Computing with Terms and Graphs, Satellite Event of ETAPS 2009, Mar 2009, York, United Kingdom. Electronic Notes in Theoretical Computer Science, Elsevier. Preprint <inria-00418560>, https://hal.inria.fr/inria-00418560

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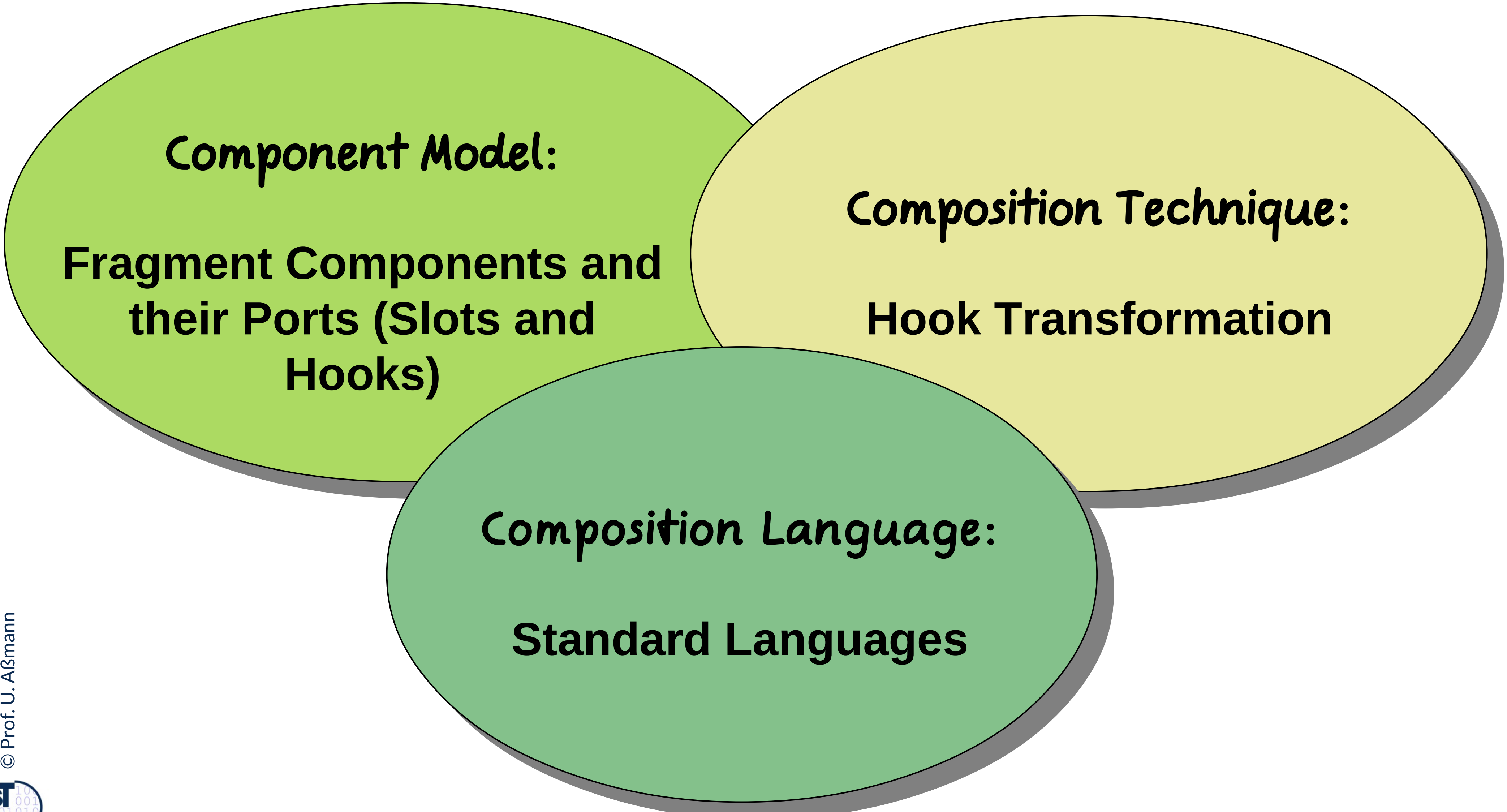
"Invasive" Composition (Typed Templating) with Port-Graph Algebrae



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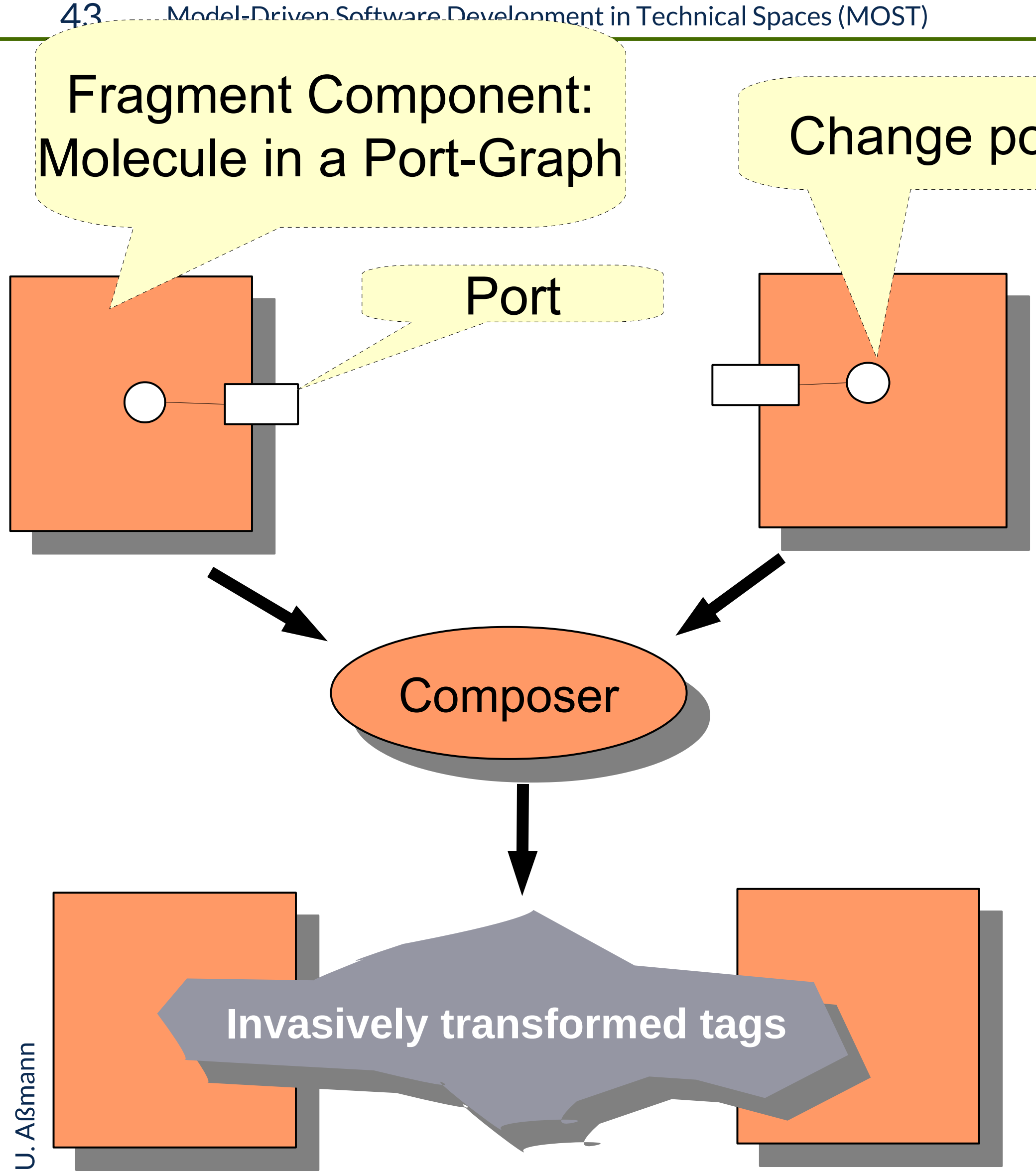
Invasive Composition as Hook Transformations



- A **port graph** is a graph in which each node (**molecule**) has a set of *ports*
- A **fragment component** is a molecule with ports (slots, hooks, query points) related to change points

Invasive Composition adapts and extends fragment components at ports (slots, hooks, query-points) by composition operators

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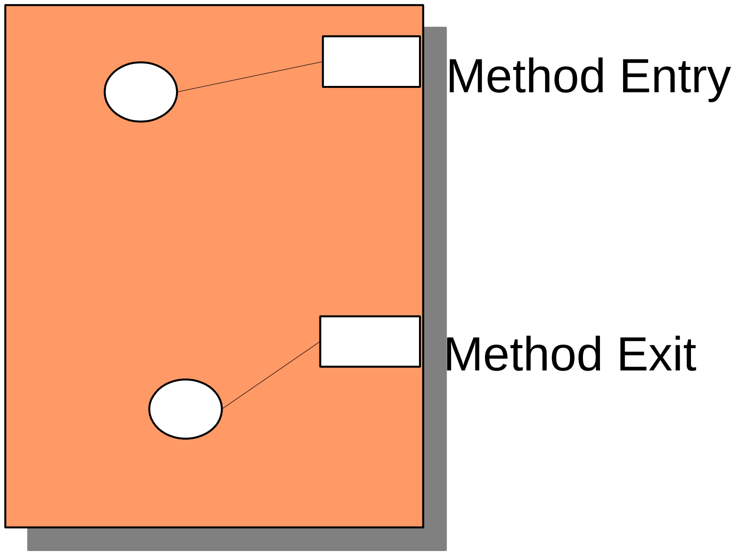
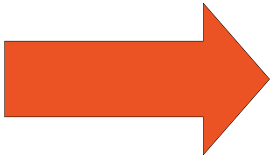
Binding Implicit Hooks with Fragments

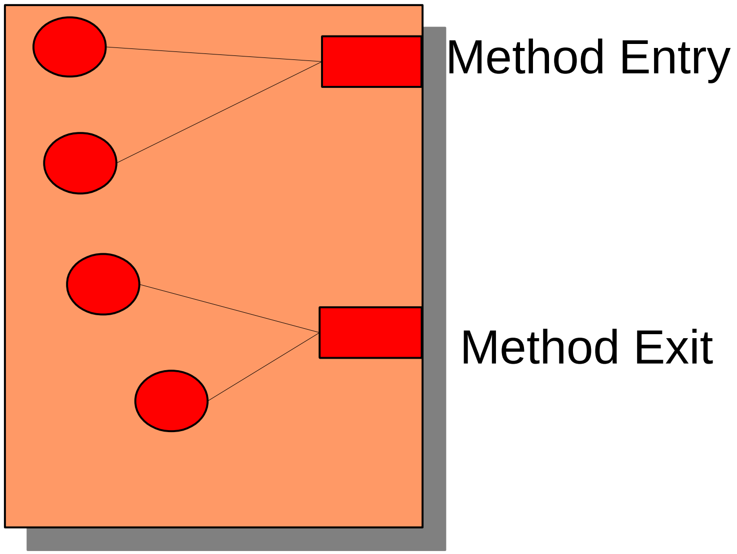



```
m (){

    abc..
    cde..

}
```






```
m (){
    print(“enter m”);
    abc..
    cde..
    print(“exit m”);
}
```

```
component.findHook(„.MethodEntry“).extend(“print(\”enter m\”);”);

component.findHook(„MethodExit“).extend(“print(\”exit m\”);”);
```

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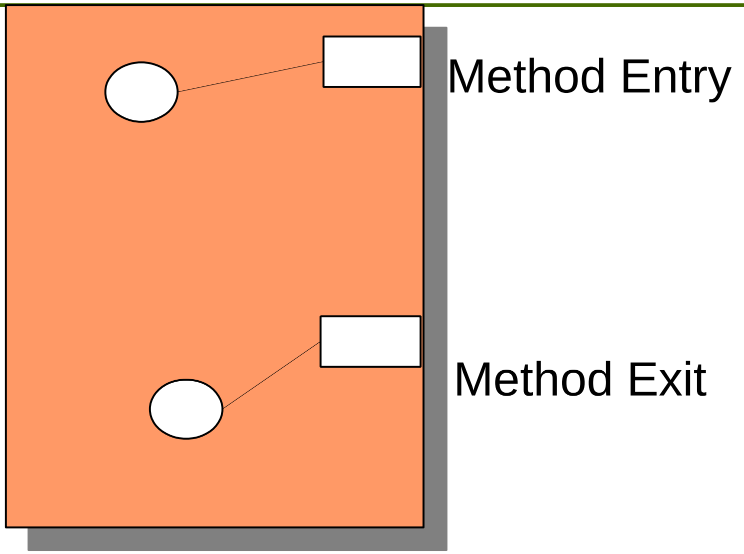
Partial Parsing of Fragment Components




```
m (){

    abc..
    cde..

}
```

```
m (){
    // Method Entry
    abc..
    cde..
    // Method Exit
}
```

Component = compositionSystem.partialParser(„m (){ abc.. cde.. }“);

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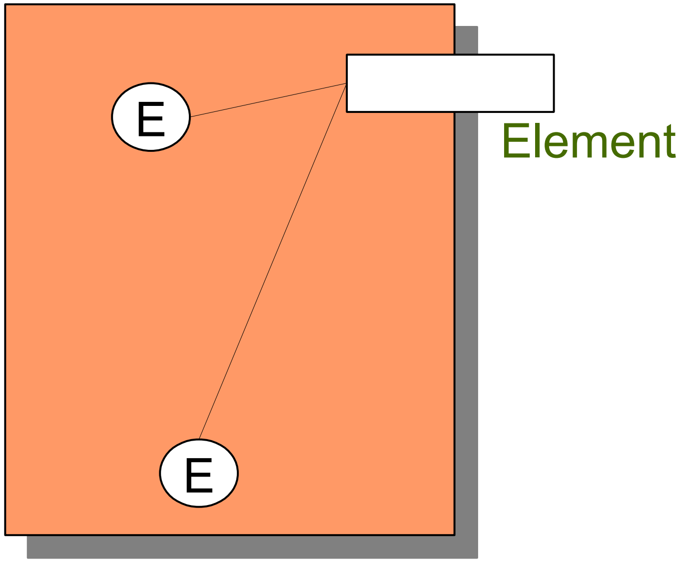
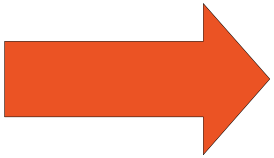
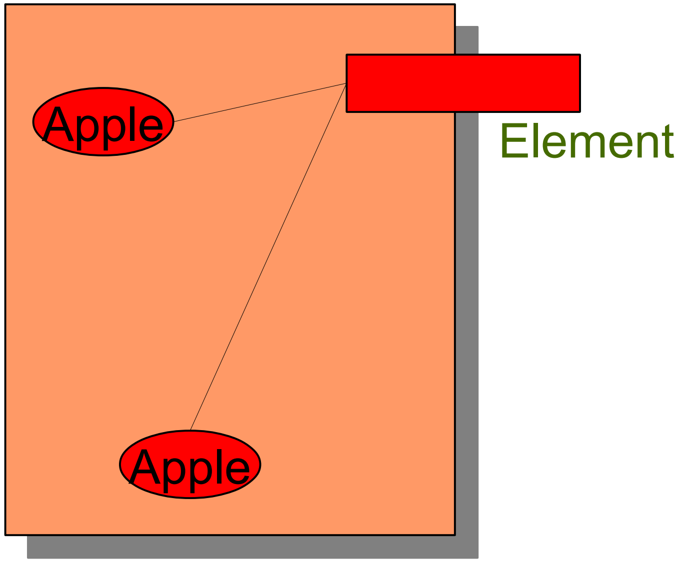
Binding Declared Hooks with Fragments







List(E) list;

....
list.add(new E());

...

List(Apple) list;

....
list.add(new Apple());

...

```
box.findHook(„Element“).bind(“Apple”);
```

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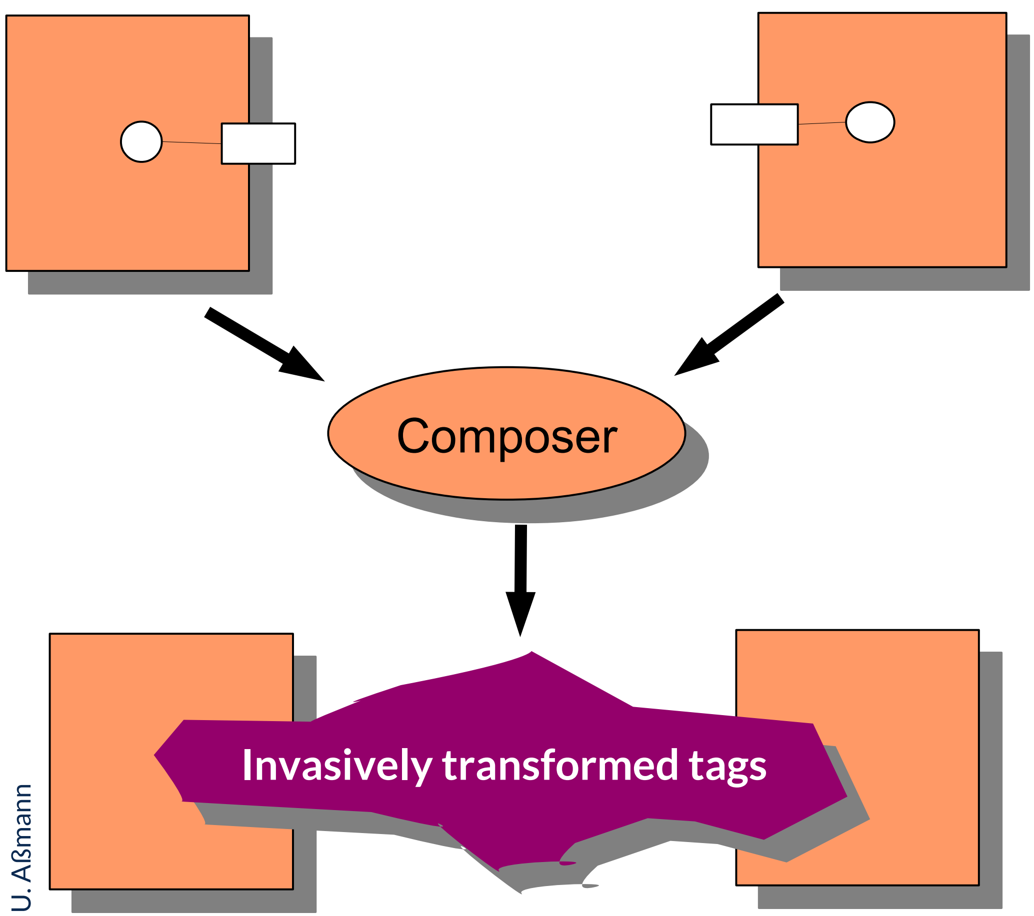
Invasive Composition as Hook Transformations



- Invasive Composition works uniformly on
  - For all languages
  - For declared hooks and implicit hooks
- Allows for unification of
  - Inheritance
  - Views
  - Aspect weaving
  - Parameterization
  - Role model merging

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Operators in a Port-Graph Algebra

Simple composition operators

- **bind** hook (parameterize)
  - generic programming
- **rename** component, rename hook
- **remove** value from hook (unbind)
- **extend** component or hook
  - extensions
- **copy** fragment component

Compound composition operators

- **inheritance** from component
  - object-oriented programming
- **view** of component
  - view-based programming
- **connect** hook 1 and 2
  - connector-based programming
- **distribute** component over other component
  - aspect weaving

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10.6 Pseudocode and Markup Languages

http://en.wikipedia.org/wiki/Pseudocode

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

Pseudocode

- **Pseudocode** consists of *structured text with keywords and blocks*, z. B. **seq, endseq, if, then, else, endif, while, endwhile, call, action, stop,...**
  - Natural text is enclosed as comment, but ignored
- For pseudocode, grammars can be constructed:
  - Syntax checking with ***island parsing***
  - An ***island grammar*** contains
    - "islands" for the keywords and structure
    - "water" for the free-form text
- Tool support:
  - Code generation (code templates and comments)
  - Documentation generation (structograms, LaTeX document generation)

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Examples for Pseudocode

- In pseudocode, structure can be recognized (as islands in the free-form water)
- Pseudocode can recognize names and do a name analysis:
  - Title of procedures, classes, and processes
  - Types from the data dictionary, Local names
- Pseudocode can define macros

```
process empfangen_Patient 1.3.1
for &Patient
       with >Bestelldatum = Datum in &Termine und >Beschwerden
        if Name*des Patienten* in &Patient
       else "aktualisieren_Patient 1.1"
       if keine >Beschwerden und >Bestelldatum ungueltig
                then „vergeben_Termin 1.2“
       else Uebernahme Patientendaten aus &Patient
       alle Unterlagen fuer Arzt aufbereiten
        <Aufnahme Name*des Patienten* in &Warteliste
       if @Bestdat+Zeit = Kalenderdatum + Uhrzeit
        then Terminpatient Platz m+1*
                vorhergehender Terminpatient m*
        else Platz n+1*n Anzahl aller Patienten im Wartezimmer*
```

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Structural Skelecon of Pseudocode (2)


```
action empfangen_Patient
       while (Patienten oder Praxisoeffnung)
       seq Eingabe >Bestelldatum, >Beschwerden
       if (@Bestdat+Uhrzeit enth. &Termine)
       then Bestellpatient
       else if (@Gebdatum+Name enth. &Patient)
              then ziehen Patientenakte
              else call aktualisieren_Patientendaten
            endif
            if (>Beschwerden <> 0*vorhanden*)
              then Unbestellter_Patient
              else call vergeben_Termin
            endif endif
      Aufbereiten aller Unterlagen fuer Arzt endseq
       if (Bestellpatient)
              then <Aufnahme Platz m+1 in &Warteliste
              else <Aufnahme Platz n+1 in &Warteliste
       endif endwhile
stop
```

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LATEX, XML and Pseudocode

- Markup languages structure pseucocode with **markup tags.**

```
\documentclass{article}

\title{My first Document}
\author{John Doe}
\usepackage[english]{babel}

\begin{document}

\maketitle

Hello World! My name is John Doe.

\emph{Next paragraph has to be written.}

\end{document}
```

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Support for Pseudocode

- LaTeX-distributions have good style packages for pseudocode:
  - algorithms.sty
  - \usepackage{algpseudocode}
  - \usepackage{algorithmicx}
  - listings.sty
- See also ELAN, the semi-natural programming language
  - http://de.wikipedia.org/wiki/ELAN
  - Part of OS L3, predecessor of L4

```
PACKET stack handling DEFINES push,pop,init
stack:
  LET max = 1000;
  ROW max INT VAR stack;
  INT VAR stack pointer;
  PROC init stack:
    stack pointer := 0
  END PROC init stack;
  PROC push (INT CONST dazu wert):
    stack pointer INCR 1;
    IF stack pointer > max
      THEN errorstop ("stack overflow")
      ELSE stack [stack pointer] := dazu wert
    END IF
  END PROC push;

  PROC pop (INT VAR von wert):
    IF stack pointer = 0
      THEN errorstop ("stack empty")
      ELSE von wert := stack [stack pointer];
           stack pointer DECR 1
    END IF
  END PROC pop

END PACKET stack handling;
```

- http://os.inf.tu-dresden.de/L3/usrman/node10.html

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Summary

- Parser generators belong to the tool set of a software engineer
- Parsers can parse
  - Texts (lines of rows)
  - CSV relations (lines of delimiter-separated tuples)
  - Pseudocode with island grammars
- The parser only parses the context-free structure of the programms, document, or model;
- Syntax trees are built from a mapping of concrete to abstract syntax
- Context conditions, integrity and wellformedness constraints are delayed to the *static semantic analysis* on the syntax tree

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The End

- Why is a parser often delivering several results (parses)?
- How can you disambiguate ambiguate rules?
- Why is string parsing not the same as tree parsing? What is the difference of concrete and abstract syntax trees?

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