Dryad & Java Front

Infrastructure for Java Transformation Systems

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Martin Bravenboer

Department of Information & Computing Sciences
Utrecht University,
The Netherlands

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Planet Stratego/XT

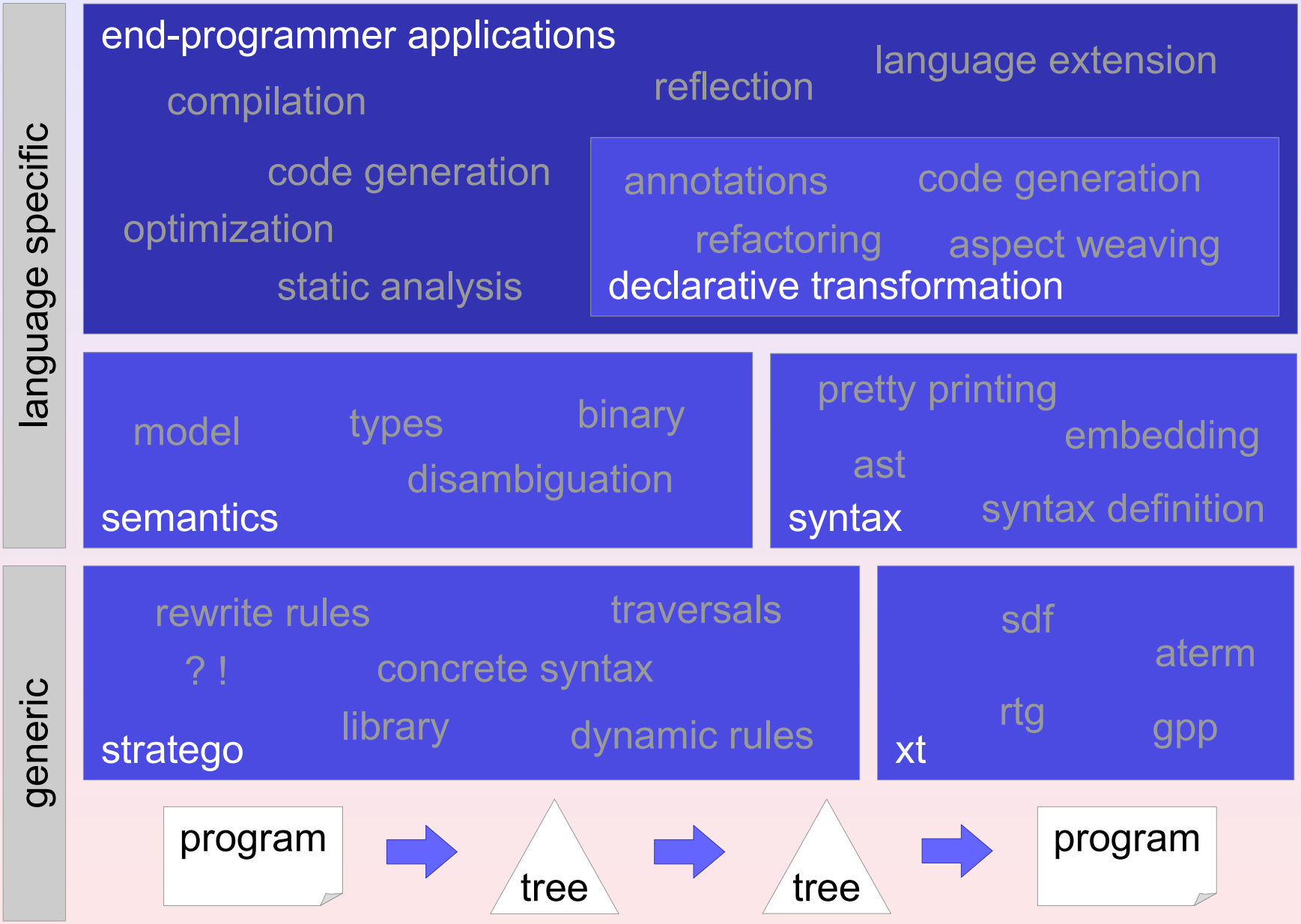
- **Stratego** – Generic language for program transformation
- **XT** – Generic infrastructure for transformation systems
- **XT Orbit** – Language specific tools

Satellite Java

- **Java Front**: Syntax related infrastructure for Java
- **Dryad**: Components for Java transformation systems
- **AspectJ Front**: extension of Java Front

Goals

- Complete tool set for Java meta-programming systems
- Compatible and up to date
- Validation: apply Stratego/XT to real-life language
- World domination


language specific
end-programmer applications
compilation
code generation
optimization
static analysis
reflection
language extension
annotations
code generation
refactoring
aspect weaving
declarative transformation
model
types
binary
disambiguation
semantics
pretty printing
embedding
ast
syntax definition
syntax
generic
rewrite rules
traversals
? !
concrete syntax
library
dynamic rules
stratego
sdf
aterm
rtg
gpp
xt
program
tree
tree
program

Java Front

- **Syntax Definition**
- **Parser**
- **Pretty-Printer**
- **Embedding of Java**

Syntax Definition

SDF grammar for Java 2 version 1.5
(i.e. generics, enums, annotations, . . .)

- Modular
- Structure of Java Language Specification, 3^{rd} Edition
- Declarative disambiguation
  - Single expression non-terminal
  - Context-free priorities
  - Lexical restrictions
  - Rejections
- Integrated lexical and context-free syntax
  - Important for language extension (AspectJ)

Syntax Definition: Ambiguities

```
lexical restrictions
  "+" -/- [\+]
  ID  -/- [a-zA-Z0-9\_\$]
  FloatNumeral -/- [fFdD]

lexical syntax
  Keyword -> ID {reject}

context-free priorities ...
  > {left: Expr "*"   Expr -> Expr
           Expr "/"   Expr -> Expr }
  > {left: Expr "+"   Expr -> Expr
           Expr "-"   Expr -> Expr }
  > {left: Expr "<<"  Expr -> Expr
           Expr ">>"  Expr -> Expr }
  > {left: Expr "instanceof" RefType -> Expr
           Expr "<"   Expr -> Expr
           Expr ">"   Expr -> Expr }
  > {left: Expr "=="  Expr -> Expr
           Expr "!="  Expr -> Expr }
  >        Expr "&"   Expr -> Expr
  >        Expr "^"   Expr -> Expr
  >        Expr "|"   Expr -> Expr ...
```

Syntax Definition: Ambiguities: Cast Expressions

JLS: Cast Expressions

(ReferenceType) UnaryExpressionNotPlusMinus
(PrimitiveType) UnaryExpression

JLS: Different Priorities

```
$ echo "(Integer) - 2" | parse-java -s Expr | pp-aterm
Minus(ExprName(Id("Integer")), Lit(Deci("2")))

$ echo "(Integer) (- 2)" | parse-java -s Expr | pp-aterm
CastRef(
  ClassOrInterfaceType(TypeName(Id("Integer")), None)
, Minus(Lit(Deci("2")))
)

$ echo "(int) - 2" | parse-java -s Expr | pp-aterm
CastPrim(Int, Minus(Lit(Deci("2"))))
```

Compare to C: syntactical ambiguity (see Transformers)

Syntax Definition: Ambiguities: Cast Expressions

Java Front: Cast Expressions

```
"(" PrimType ")" Expr -> Expr {cons("CastPrim")}
"(" RefType  ")" Expr -> Expr {cons("CastRef")}
PrimType -> Type
RefType  -> Type
```

Java Front: Cast Priorities

```
context-free priorities
  "(" RefType ")" Expr -> Expr
> { "++"  Expr -> Expr
    "--"  Expr -> Expr
    "+"   Expr -> Expr
    "-"   Expr -> Expr }

context-free priorities
  "(" PrimType ")" Expr -> Expr
> {left:
    Expr "*" Expr -> Expr
    Expr "/" Expr -> Expr
    Expr "%" Expr -> Expr }
```

Syntax Definition: Context-Dependent Ambiguities

Java is an ambiguous language

- `import java.util.ArrayList`

Package, typename

```
TypeImportDec(
  TypeName(
    PackageOrTypeName(PackageOrTypeName(Id("java")), Id("util"))
  , Id("ArrayList")
  )
)
```

- `System.out.println("Hello world")`

Package, typename, field, local variable

```
MethodName(
  AmbName(AmbName(Id("System")), Id("out"))
, Id("println")
)
```

Syntax Definition: How to Handle Ambiguities?

- Preserve ambiguities: parse forest (GLR)
- Generalize syntactic sorts: `PackageOrTypeName`, `AmbiguousName`, `ClassOrInterfaceType`

JLS: Mixture

```
ReferenceType:
    ClassOrInterfaceType
    TypeVariable

ClassOrInterfaceType:
    ClassType
    InterfaceType

PackageOrTypeName
    Identifier
    PackageOrTypeName . Identifier

ExpressionName:
    Identifier
    AmbiguousName . Identifier
```

Syntax Definition: Context-Dependent Ambiguities

Java Front

- Non-ambiguous (ambiguities encoded in grammar)
- e.g. `PackageOrTypeName`, `AmbName`, `ClassOrInterfaceType`

Alternative: Preserve

- Use Generalized LR and parse forest (a la Transformers)
- Declarative syntax definition
- Performance? Embedding?
- Would like to experiment with this: already have disambiguating type checker.

Alternative parsing technology resulted in various fixes in the JLS itself!

Parser and Pretty-Printer

`parse-java` and `pp-java`

- Supports comment preservation (e.g. Javadoc)

`parse-java`

- Supports preserving position information

`pp-java`

- Hand-crafted in Stratego/Box
  - Good-case and worst-case formatting
  - Full Stratego pattern-matching
- Preserves priorities
  - Inserts parentheses where necessary
  - generated from SDF syntax definition

Java Front: Testing

Functional tests: roundtrip

- GNU Classpath and J2SDK
- `ast = parse; ast' = parse | pp | parse; compare`
- Found various bugs in syntax definition and pretty-printer

Unit tests: parse unit

```
test always take longest match for --
  "1--2" fails

test multiplication has higher priority than addition
  "1 + 2 * 3" -> Plus(_, Mul(_, _))

test Cast operators 1
  "(int) -1" -> CastPrim(_, Minus(_))

test Cast operators 8
  "(Integer) -1 " -> Minus(ExprName(Id("Integer")),Lit(Deci("1")))
```

Embedding of Java

Concrete syntax for Java in meta language

- Stratego-Java-15

```
Explode(r) :
  bstm |[ for(lvdec; e1; e*) stm ]| -> |[
       ForStatement x1 = _ast.newForStatement();
       x1.setBody(e2);
       x1.setExpression(e3);
       x1.initializers().add(~e: <r> lvdec);
       java.util.List x2 = x1.updaters();
       bstm2*
     ]| where ...

insert-admin(|x_matcher, x_admin) :
  bstm |[ if( x_matcher.lookingAt() ) {
             bstm_inner*
           } else { bstm* }
       ]| ->
  bstm |[ if( x_matcher.lookingAt() ) {
             x_admin = x_matcher.end();
             bstm_inner*
           } else { bstm* }
       ]|
```

Embedding of Java

- Generic embedding: parameterized with expression sort of meta language
- Explicit disambiguation

```
module Embedded-Java-15[E]
imports Java-15-Prefixed
exports
  variables
    [ij]  [0-9]*  -> JavaDeciLiteral {prefer}
    [xyz] [0-9]*  -> JavaID          {prefer}
    "e"   [0-9]*  -> JavaExpr        {prefer}

  context-free syntax
            "|[" JavaBlockStm  "]|" -> E {cons("ToMetaExpr")}
    "bstm"  "|[" JavaBlockStm  "]|" -> E {cons("ToMetaExpr")}
    "bstm*" "|[" JavaBlockStm* "]|" -> E {cons("ToMetaListExpr")}

    "~"  E ->  JavaExpr         {cons("FromMetaExpr")}
    "~*" E -> {JavaExpr ","}*   {cons("FromMetaExpr")}
```

Beyond support for Java syntax

- Java Bytecode $\leftrightarrow$ ATerm bridge
- Dryad Library
  - Model for Java source and bytecode
  - Implementation of JLS definitions
- Reclassification (disambiguation) and qualification
- Type checker

Invaluable for the implementation of a Java transformation system!

Java Bytecode ↔ ATerm Bridge

- Access to bytecode is important for semantic analysis
  - Disambiguation and type-checking (used extensively)
- Bytecode represented in ATerm
  - Follows structure of the JVM Specification
  - Signature: `dryad/bytecode/signature`
- Disassembler: `class2aterm`
  - Generics Signatures
  - Local variables tables, line numbers, etc.
  - Code optional (`-c`)
- Assembler: `aterm2class`
- Implemented in Java, based on Apache's BCEL and Java ATerm Library

Java Bytecode ↔ ATerm Bridge

```
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;

public class Foo implements ActionListener
{
  public void actionPerformed(ActionEvent e)
  {
    String msg = "Don't push me!";
    System.out.println(msg);
  }
}
```

Java Bytecode ↔ ATerm Bridge

```
ClassFile(
  MinorVersion(0), MajorVersion(49)
, AccessFlags([Super, Public])
, ThisClass("Foo")
, SuperClass(Some("java.lang.Object"))
, Interfaces(["java.awt.event.ActionListener"])
, Fields([])
, Methods([
    Method(
      AccessFlags([Public])
    , Name("<init>")
    , MethodDescriptor([], Void)
    , Attributes([])
    )
  , Method(
      AccessFlags([Public])
    , Name("actionPerformed")
    , MethodDescriptor([ObjectType("java.awt.event.ActionEvent")], Void)
    , Attributes([])
    )
  ])
, Attributes([SourceFile("Foo.java")])
)
```

Java Bytecode ↔ ATerm Bridge

```
Code(
  MaxStack(Some(2))
, MaxLocals(Some(3))
, Instructions([
     LDC(String("Don't push me!"))
   , ASTORE(2)
   , GETSTATIC(
       FieldRef(Class("java.lang.System"), Name("out")
       , FieldDescriptor(ObjectType("java.io.PrintStream")))
     )
  , ALOAD(2)
  , INVOKEVIRTUAL(
      MethodRef(
        Class("java.io.PrintStream"), Name("println")
      , MethodDescriptor([ObjectType("java.lang.String")], Void)
      )
    )
  , RETURN
  ])
, ExceptionTable([])
, Attributes([])
)
```

Dryad Library

Dryad Model

- `dryad/model/-`: representation of source and bytecode
- Object oriented
- Global structure linked: `get-superclass`, etc.
- `get-methods`, `get-fields`, `get-formal-parameter-types`, ...
- Abstraction over source code or bytecode

JLS definitions

- Based on model
- Conversions and types
- For example: `is-assignment-convertable(|`*t*`)`, `supertypes`, `is-subtype(|`*type*`)`
- `<proper-supertypes> Int() => [Long, Float, Double]`
- Many of these definitions are non-trivial

Dryad: Reclassification and Qualification

`dryad-front (dryad-reclassify-ambnames)`

- Reclassification (names, types)
  - Contextually dependendent names
- Qualification (types)
  - Unqualified names are hard too handle
  - Use fully qualified names in transformations

Complex

- Imports, on demand imports, static imports
- Inner classes, non-trivial rules for visibility and shadowing
- Complex scoping rules
  - Even bugs in Sun's Java compiler
  - ...and the JLS
- Transformation should not be bothered with this

Implementation

- Strategies and scoped dynamic rules

Dryad R&Q: TypeName versus PackageName

Java Source

```
import java.util.ArrayList;
```

Parse

```
TypeImportDec(
  TypeName(
    PackageOrTypeName(
      PackageOrTypeName(Id("java")), Id("util")
    )
  , Id("ArrayList")
  ))
```

Reclassify

```
TypeImportDec(
  TypeName(
    PackageName([Id("java"), Id("util")])
  , Id("ArrayList")
  ))
```

Dryad R&Q: AmbName

Java Source

```
System.out.println("Hello World!");
```

Parse

```
MethodName(
  AmbName(AmbName(Id("System")), Id("out"))
, Id("println"))
```

Reclassify

```
MethodName(
  ExprName(
    TypeName(PackageName([Id("java"), Id("lang")])
    , Id("System"))
  , Id("out")
  )
, Id("println"))
```

Dryad R&Q: ClassType, InterfaceType and Qualification

Java Source

```
import java.util.List;

public class Foo {
  List getFoo() {};
}
```

Parse

```
MethodDecHead(...,
  ClassOrInterfaceType(TypeName(Id("List")), None)
  ... )
```

Reclassify

```
MethodDecHead(...,
  InterfaceType(
    TypeName(PackageName([Id("java"), Id("util")])
    , Id("List")), None)
  ...)
```

Dryad Type Checker

`dryad-front --tc on (dryad-type-checker)`

- Annotates expressions with their types . . . or not
- Type-aware transformations
  - e.g. extract method, inner class lifting
- Also available as a library
  - `dryad/type-check/-`
- Implementation: rewrite-rules and scoped dynamic rules

Status

- Basic operators and method resolution works
- But, not yet complete: no inner classes, no access modifiers
- No error reporting: only annotation
- `dryad-vis-tc-jtree`: show untyped expressions

Dryad Type Checker

System.out.println("Hello World!")

```
Invoke(
  Method(
    MethodName(
      ExprName(
        TypeName(PackageName([Id("java"), Id("lang")]) , Id("System"))
      , Id("out")
      ){ ClassType(
           TypeName(PackageName([Id("java"), Id("io")])
           , Id("PrintStream"))
         , None
         )
       }
    , Id("println")
    )
  )
, [ Lit(String([Chars("Hello World!")])){
      ClassType(TypeName(PackageName([Id("java"), Id("lang")]),
        Id("String")), None)}
  ]
){Void}
```

Application: JavaJava

Embed Java syntax in Java

```
context-free syntax
  "type" "|[" Type "]|" -> MetaExpr {cons("ToMetaExpr")}

variables
  "e" [0-9]*      -> Expr          {prefer}
  "e" [0-9]* "*" -> {Expr ","}*   {prefer}
```

Assimilation rules for Eclipse JDT Core API

```
  Assimilate(r) :
    type |[ double ]| -> |[ ast.newPrimitiveType(PrimitiveType.DOUBLE) ]|

  Assimilate(r) :
    |[ y(e*) ]| -> |[
      {| MethodInvocation x = ast.newMethodInvocation();
         x.setName(ast.newSimpleName("~y"));
         bstm* | x |}
    ]|
    where <newname> "inv" => x
        ; <ExplodeArgs(r | x)> e* => bstm*
```

JavaJava: Ambiguities

Problem: explicit disambiguation in JavaJava

- Indicate syntactic sort in (anti-)quotations
- Naming convention for variables

```
String x = "Foo";

CompilationUnit dec = compilation-unit |[
  public class x {
    public static void main(String[] args) {
      System.out.println("Hello world");
    }
  } ]|;
```

Solution: type-based disambiguation

- No explicit disambiguation: parse forest
- Ambiguities eliminated in extension of Dryad type checker

JavaJava: Ambiguous Embedding

```
context-free syntax
  "|[" CompUnit  "]|" -> MetaExpr {cons("ToMetaExpr")}
  "|[" TypeDec   "]|" -> MetaExpr {cons("ToMetaExpr")}
  "|[" BlockStm  "]|" -> MetaExpr {cons("ToMetaExpr")}
  "|[" BlockStm* "]|" -> MetaExpr {cons("ToMetaExpr")}

context-free syntax
  "#[" MetaExpr "]"-> ID   {cons("FromMetaExpr")}
  "#[" MetaExpr "]"-> Expr {cons("FromMetaExpr")}

variables
  MetaVarID -> ID
  MetaVarID -> Expr
  MetaVarID -> {Expr ","}+

lexical syntax
  [A-Za-z\_\$][A-Za-z0-9\_\$]* -> MetaVarID
```

JavaJava: Disambiguation

```
Assign(ExprName(Id("dec")),
       1> ToMetaExpr(  CompUnit(... ClassDec(... Id("Foo")...) ...)  )
       2> ToMetaExpr(  ClassDec(... Id("Foo") ...)   )
       3> ToMetaExpr([ ClassDec(... Id("Foo") ...) ] ) )

1> {| CompilationUnit cu_0 = _ast.newCompilationUnit(); ...
      TypeDeclaration class_0 = _ast.newTypeDeclaration();
      class_0.setName(_ast.newSimpleName("Foo")); ... | cu_0 |}
2> {| TypeDeclaration class_1 = _ast.newTypeDeclaration();
      class_1.setName(_ast.newSimpleName("Foo")); ... |class_1 |}
3> {| List<BodyDeclaration> decs_0 = new ArrayList<BodyDeclaration>();
      decs_0.add( ... ); ... | decs_0 |}
```

Ambiguity Lifting

```
dec = 1> CompUnit 2> TypeDec 3> List<BodyDec>

1> dec = CompUnit 2> dec = TypeDec 3> dec = List<BodyDec>

 f(1> CompUnit 2> TypeDec 3> List<BodyDec>)

 1> f(CompUnit) 2> f(TypeDec) 3> f(List<BodyDec>)
```

Conclusion

- Working solid support for implementing Java transformations systems
- Some components are finished, some are work in progress

What's next?

- Full type checker
- Extensibility of components
- High-level transformation for Java
- JVM Bytecode back-end

See Also

- `http://dryad.stratego.org` – Dryad website
- `http://planet.stratego.org` – Weblog Karl, Rob & Martin