Infrastructure for Program Transformation Systems

Stratego/XT Tutorial

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Planet Stratego/XT

Stratego

- Language for program transformation
- Suitable for implementing complete programs

XT

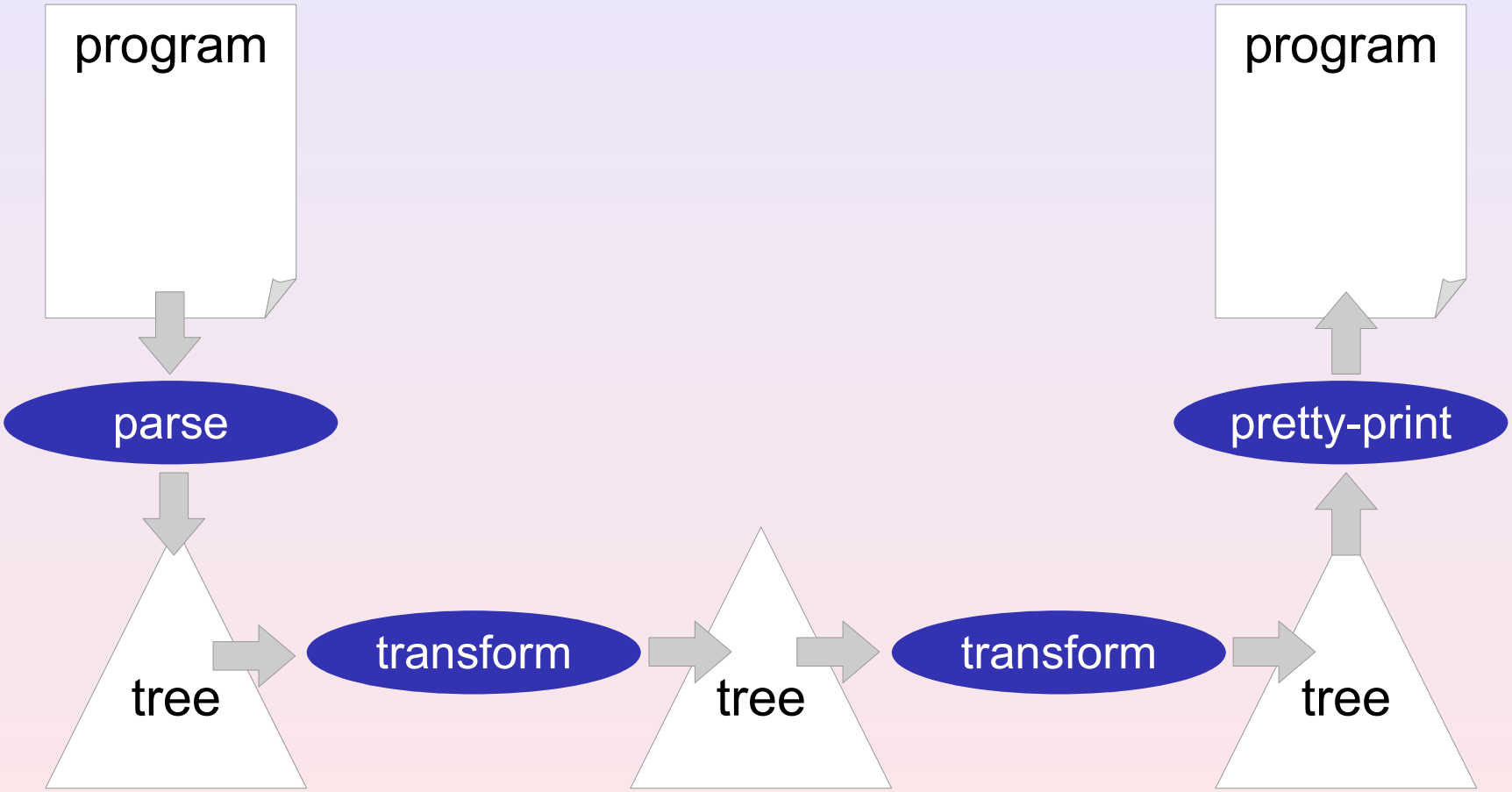
- Collection of Transformation Tools
- Infrastructure for implementing transformation systems
- Parsing, pretty-printing, interoperability

XT Orbit

- Language specific tools
- Java, C, C++, Octave, ...

This talk: the XT of Stratego/XT

Program Transformation Pipeline



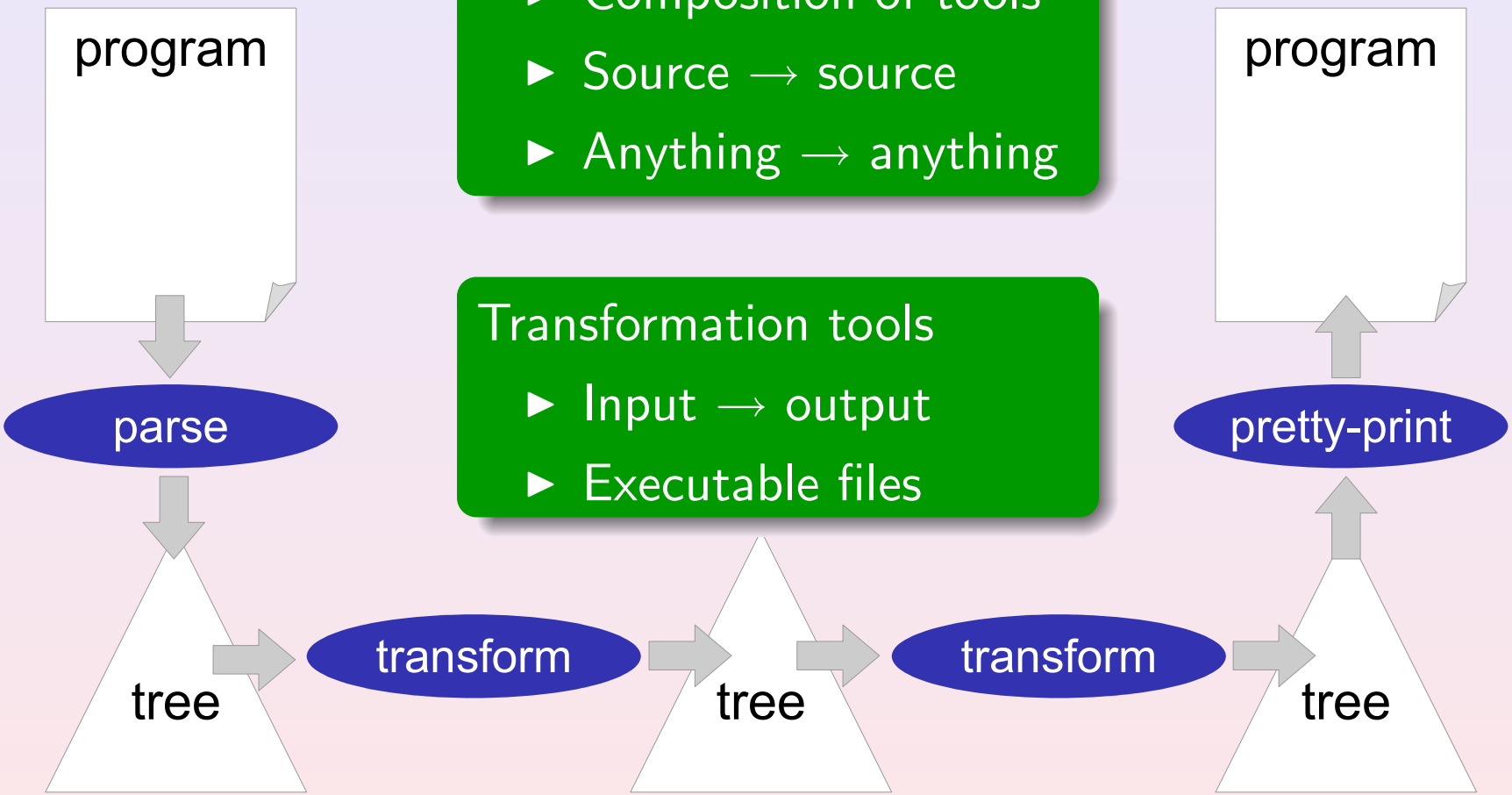
Program Transformation Pipeline

Transformation systems

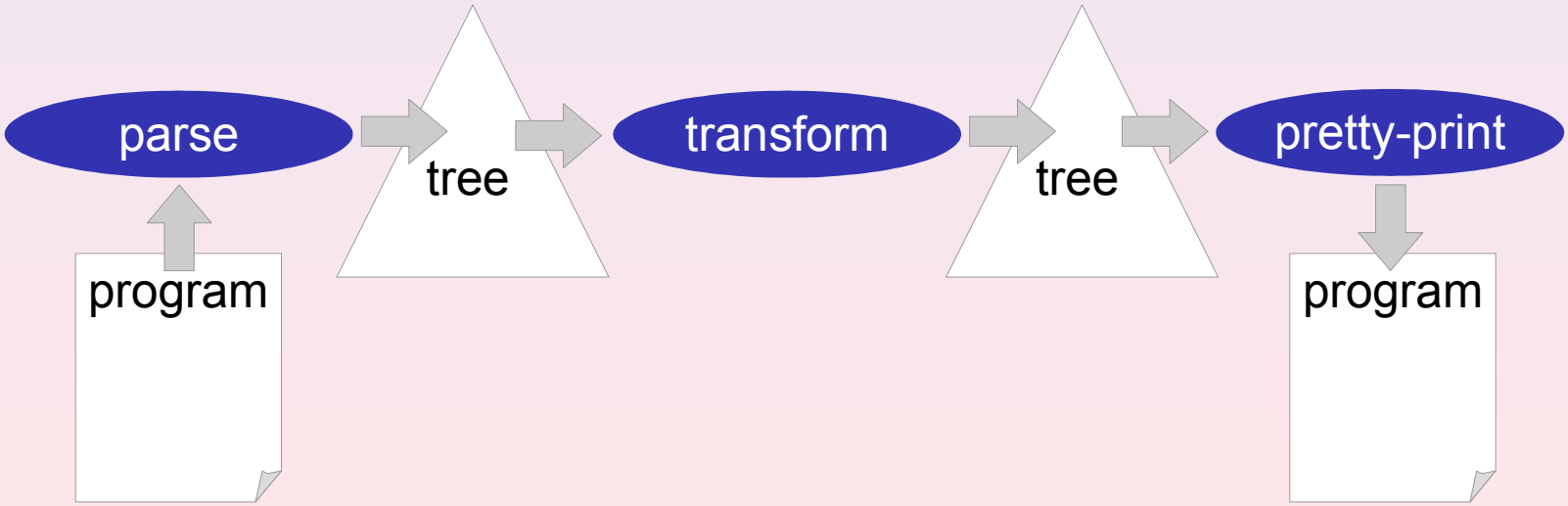
- Composition of tools
- Source → source
- Anything → anything

Transformation tools

- Input → output
- Executable files



Architecture of Stratego/XT



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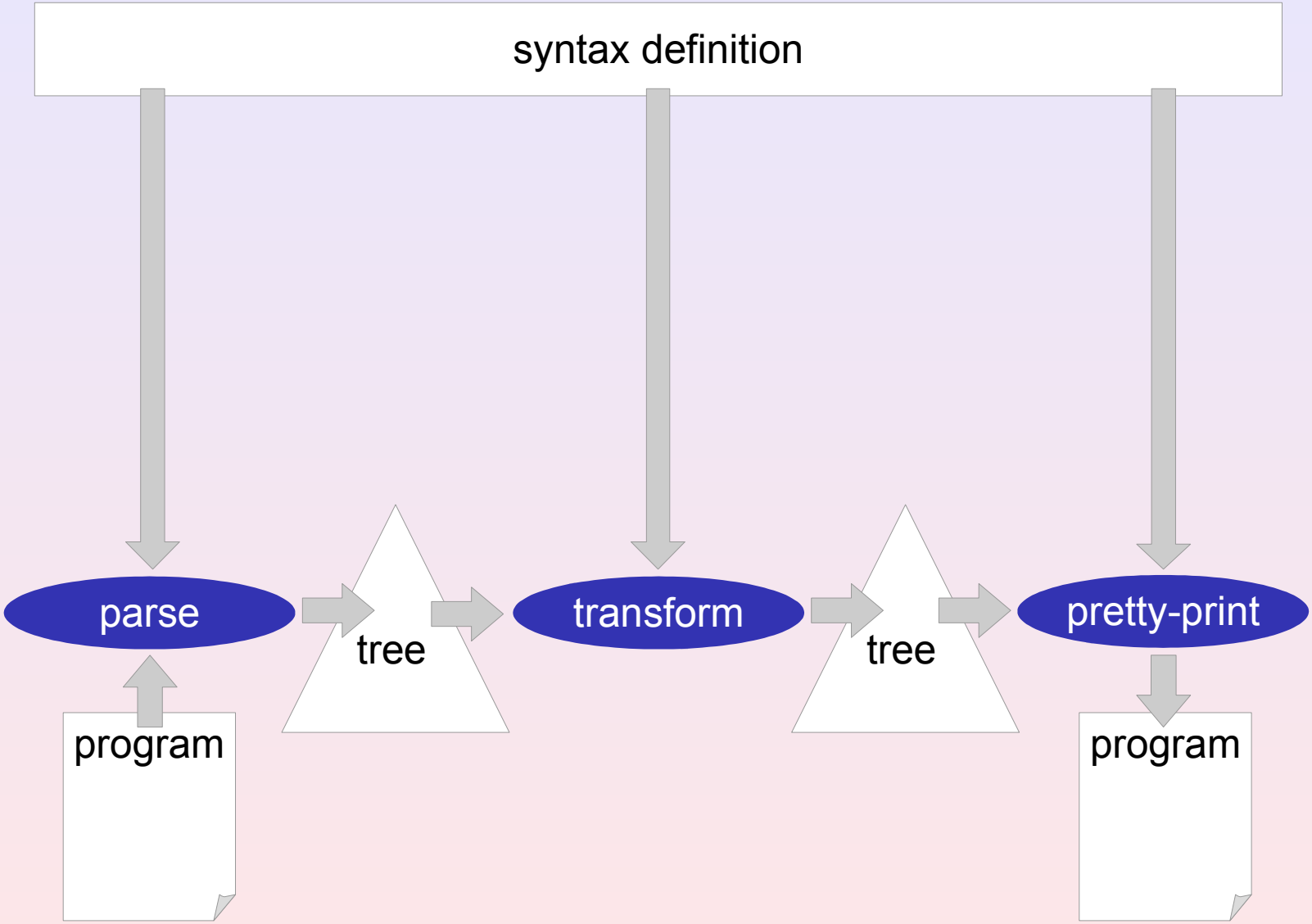

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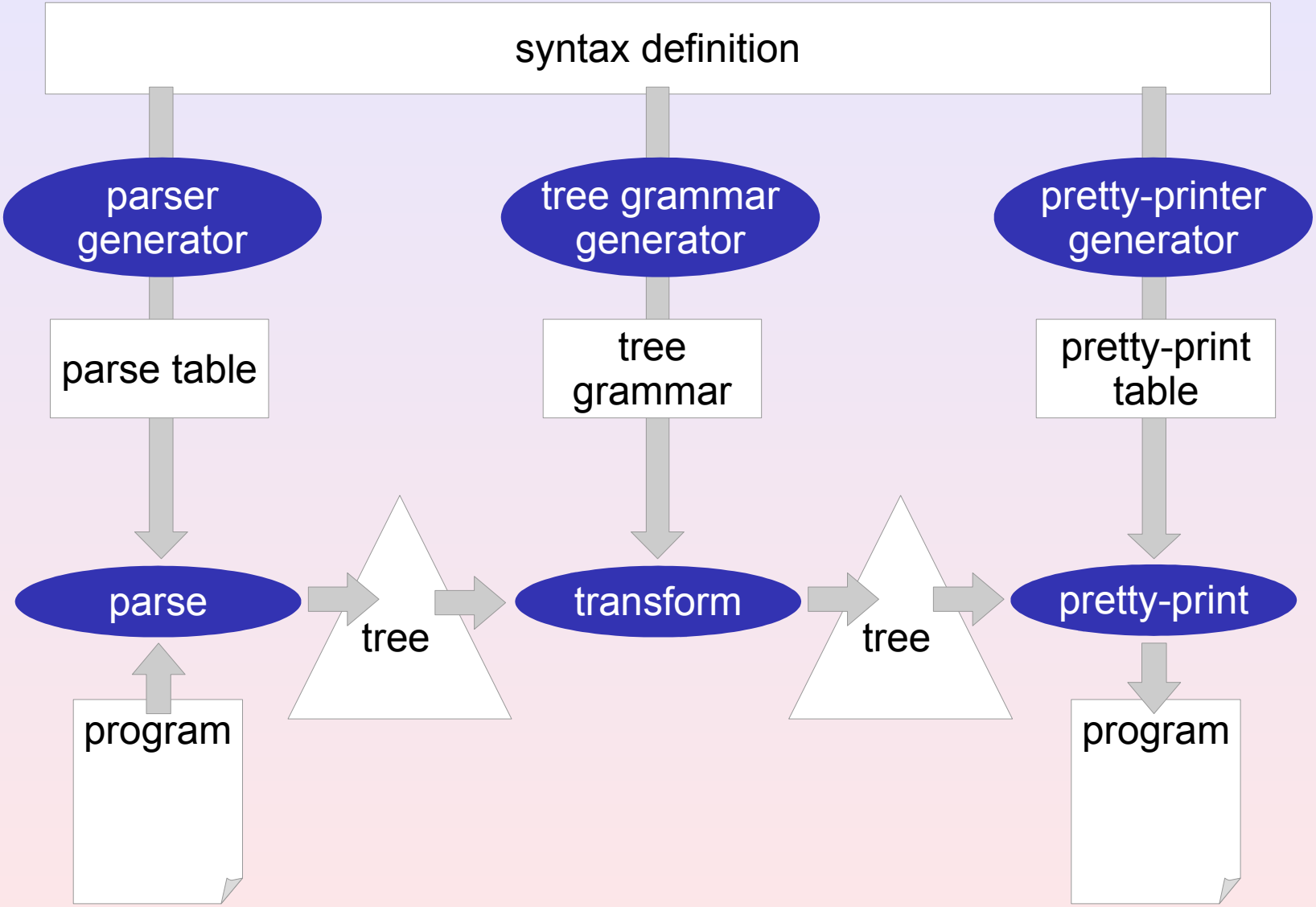

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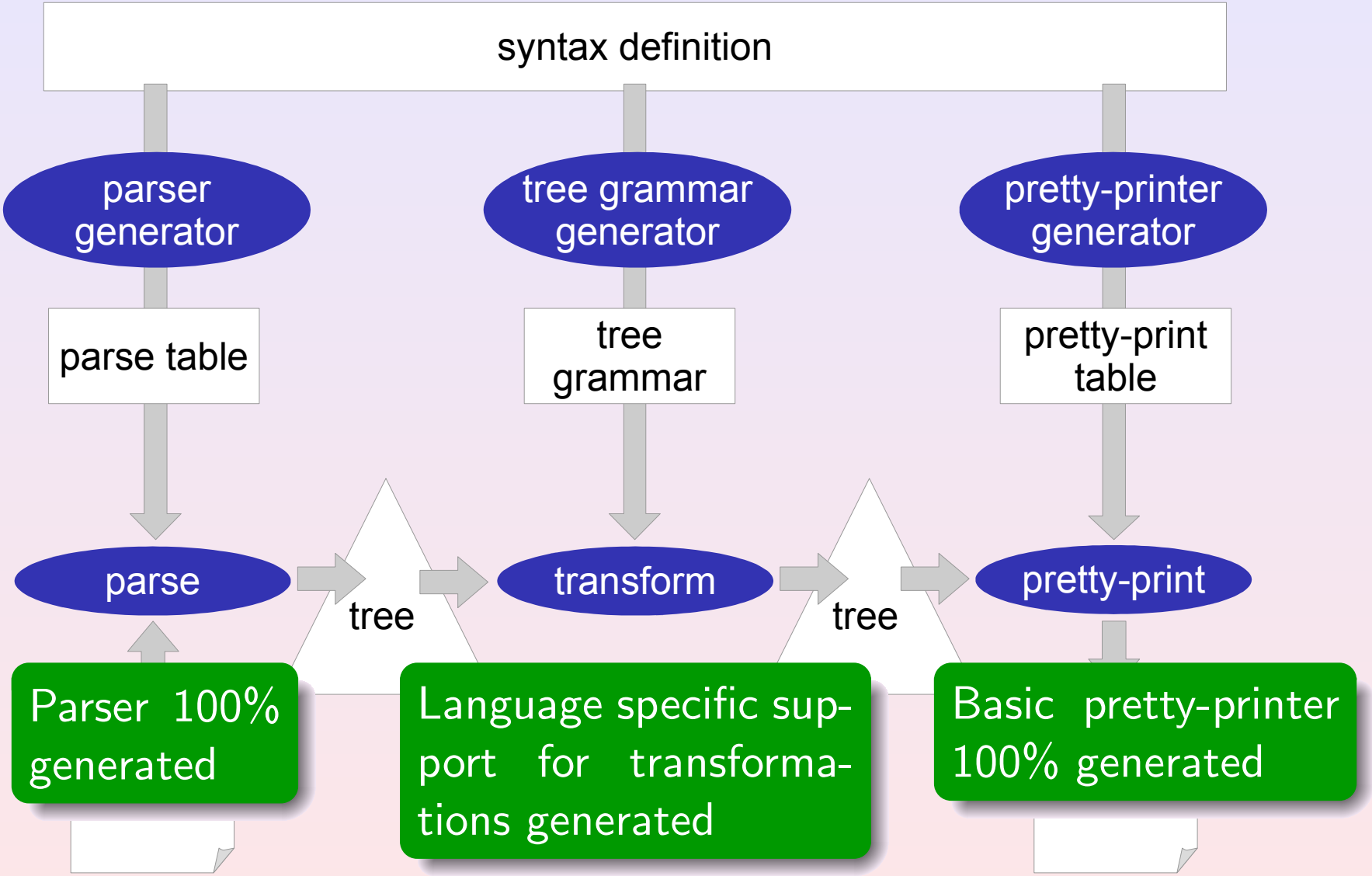
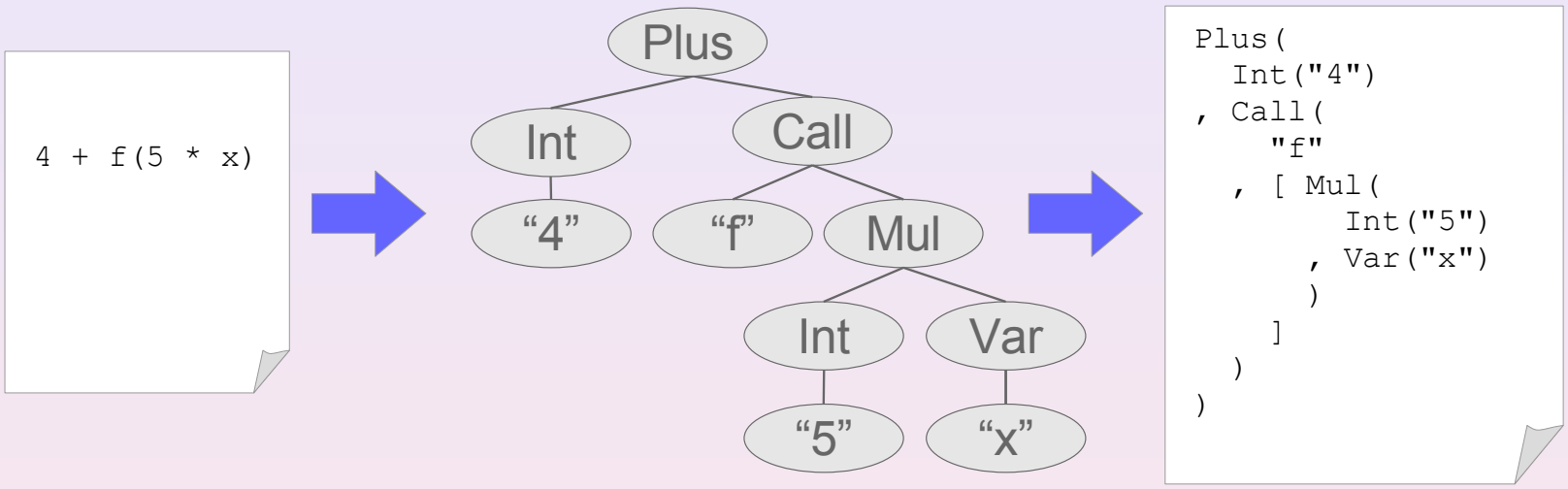


Abstract Syntax of Programs

Parser: textual representation → abstract syntax tree



Trees are represented as terms in the ATerm format

```
Plus(Int("4"), Call("f", [Mul(Int("5"), Var("x"))]))
```

ATerm Format

Application	`Void()`, `Call(`*t*`, `*t*`)`
List	`[]`, `[`*t*`, `*t*`, `*t*`]`
Tuple	`(`*t*`, `*t*`)`, `(`*t*`, `*t*`, `*t*`)`
Integer	`25`
Real	`38.87`
String	`"Hello world"`
Annotated term	*t*`{`*t*`, `*t*`, `*t*`}`

- Exchange of structured data
- Efficiency through maximal sharing
- Binary encoding

Stratego: internal is external representation
$\Rightarrow$ divide systems into smaller, reusable tools

SDF – Syntax Definition Formalism

1. **Declarative**
   - Important for code generation
   - Completely define the syntax of a language
2. **Modular**
   - Syntax definitions can be composed!
3. **Context-free and lexical syntax**
   - No separate specification of tokens for scanner
4. **Declarative disambiguation**
   - Priorities, associativity, follow restrictions
5. **All context-free grammars**
   - Beyond LALR, LR, LL

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SDF: Modular

```
module Lexical
exports
  lexical syntax
    ...
```

```
module Expressions
imports Lexical
exports
  context-free syntax
    ...
```

```
module Main
imports Expressions
exports
  context-free start-symbols Exp
```

SDF: Lexical Syntax

Lexical syntax is defined with ordinary productions.

```
module Lexical
exports
  sorts Id IntConst BoolConst
  lexical syntax
    [A-Za-z][A-Za-z0-9]* -> Id

    [0-9]+  -> IntConst
    "true"  -> BoolConst
    "false" -> BoolConst

    [\r\n\t\ ] -> LAYOUT
    "//" ~[\n]* [\n] -> LAYOUT
```

- Even *context-free* lexical syntax is possible
- Avoid complex regular expressions

SDF: Disambiguation of Lexical Syntax

Declaring reserved keywords: reject certain productions

```
lexical syntax
  "true"  -> Id {reject}
  "false" -> Id {reject}
```

Longest match: follow restriction

```
lexical restrictions
  Id       -/- [A-Za-z0-9]
  IntConst -/- [0-9]
```

Require layout after a keyword

```
lexical restrictions
  "if" -/- [A-Za-z0-9]
```

SDF: Disambiguation of Lexical Syntax

Declaring reserved keywords: reject certain productions

```
lexical syntax
  "true"  -> Id {reject}
  "false" -> Id {reject}
```

Solves ambiguity between variable and boolean constant.

```
$ echo "true" | sglri -p Example.tbl
amb([Bool("true"),Var("true")])
```

Longest match: follow restriction

```
lexical restrictions
  Id       -/- [A-Za-z0-9]
  IntConst -/- [0-9]
```

Require layout after a keyword

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Longest match: follow restriction

```
lexical restrictions
  Id       -/- [A-Za-z0-9]
  IntConst -/- [0-9]
```

Rejects unintended split of identifier

```
$ echo "xinstanceof Foo" | sglri
InstanceOf(Var("x"),"Foo")
```

Require layout after a keyword

```
lexical restrictions
  "if" -/- [A-Za-z0-9]
```

SDF: Disambiguation of Lexical Syntax

Declaring reserved keywords: reject certain productions

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lexical syntax
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```

Require layout after a keyword

```
lexical restrictions
  "if" -/- [A-Za-z0-9]
```

Rejects unintended split of keyword

```
$ echo "ifx then y" | sglri
IfThen(Var("x"),Var("y"))
```

SDF: Context-free Syntax

```
context-free syntax
  Id              -> Exp {cons("Var")}
  IntConst        -> Exp {cons("Int")}
  BoolConst       -> Exp {cons("Bool")}

  "(" Exp ")"     -> Exp {bracket}

  Exp "+" Exp     -> Exp {cons("Plus")}
  Exp "-" Exp     -> Exp {cons("Min")}
  Exp "*" Exp     -> Exp {cons("Mul")}
  Exp "/" Exp     -> Exp {cons("Div")}

  Exp "&" Exp     -> Exp {cons("And")}
  Exp "|" Exp     -> Exp {cons("Or")}
  "!" Exp         -> Exp {cons("Not")}

  Id "(" {Exp ","}* ")" -> Exp {cons("Call")}
```

SDF: Associativity of Operators

```
$ echo "1 + 2 + 3" | sglri -p Example.tbl
amb([
  Plus(Plus(Int("1"), Int("2")), Int("3"))
, Plus(Int("1"), Plus(Int("2"), Int("3")))
])
```

Declare associativity in attribute:

```
    Exp "+" Exp -> Exp {left, cons("Plus")}
    Exp ">" Exp -> Exp {non-assoc, cons("Gt")}
```

- left
- right
- assoc
- non-assoc

SDF: Priority of Operators

```
$ echo "1 + 2 * 3" | sglri -p Example.tbl
amb([
  Mul(Plus(Int("1"), Int("2")), Int("3"))
, Plus(Int("1"), Mul(Int("2"), Int("3")))
])
```

```
context-free priorities
      "!"  Exp -> Exp
  > {left:
      Exp "*" Exp -> Exp
      Exp "/" Exp -> Exp
    }
  > {left:
      Exp "+" Exp -> Exp
      Exp "-" Exp -> Exp
    }
  >   Exp "&" Exp -> Exp
  >   Exp "|" Exp -> Exp
```

Parse-unit: Testing SDF Syntax Definitions

```
testsuite Expressions
topsort Exp

test simple addition
  "2 + 3" -> Plus(Int("2"), Int("3"))

test addition is left associative
  "1 + 2 + 3" -> Plus(Plus(_, _), _)

test > is not associative
  "1 > 2 > 3" fails

test
  file foo.exp succeeds
```

```
$ parse-unit -i exp.testsuite -p Example.tbl
...
```

SDF: Parsing

Parsing Technology

SDF relies on SGLR parsing

- Scannerless: no separate lexical analysis
- Generalized LR: allows ambiguities

SDF requires an extraordinary general parsing algorithm.

Generating a parser

- Collect SDF modules into a single syntax definition

```
$ pack-sdf -i Example.sdf -o Example.def
```

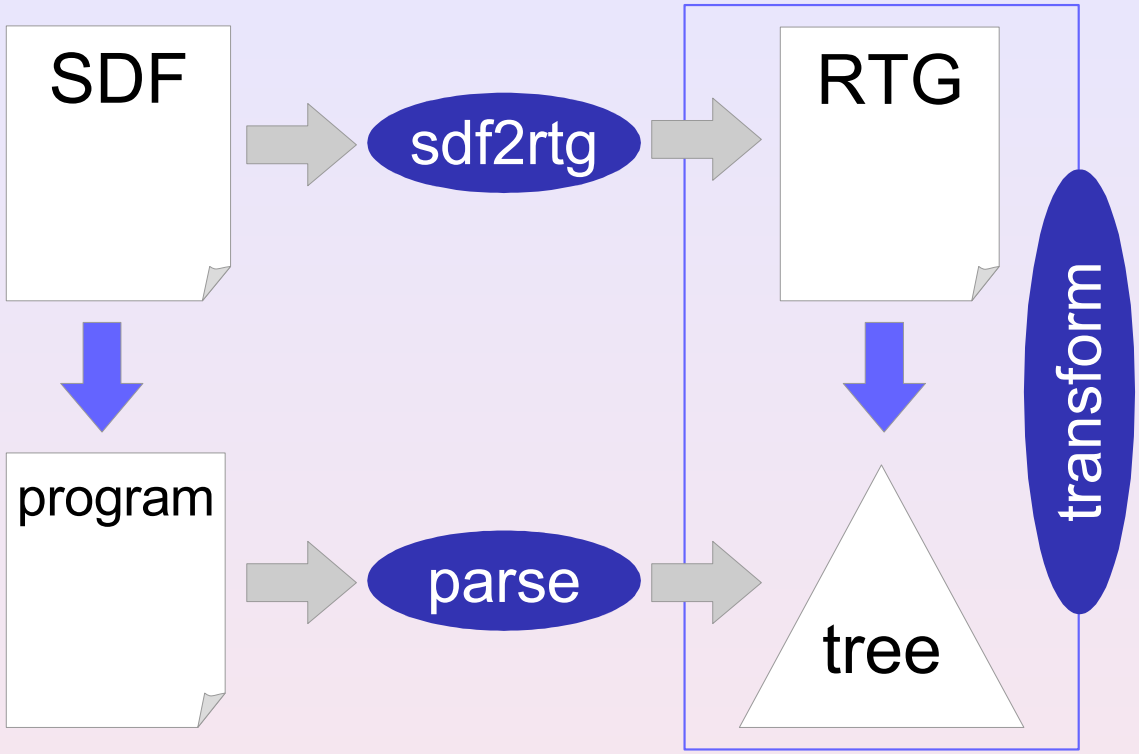
- Generate a parse-table

```
$ sdf2table -i Example.def -o Example.tbl -m Main
```

- Parse an input file

```
$ sglri -i foo.exp -p Example.tbl
```

Tree Grammars as Contracts



- Syntax definitions (grammars) define a set of strings
- Transformation tools operate on trees
- Tree grammars define the format of trees
- Used to generate tools and libraries

Regular Tree Grammars

```
regular tree grammar
  start Exp
  productions
    Exp -> Int(IntConst)
         | Bool(BoolConst)
         | Not(Exp)
         | Mul(Exp, Exp)
         | Plus(Exp, Exp)
         | Call(Id, Exps)

    Exps -> <nil>()
          | <cons>(Exp, Exps)

    BoolConst -> <string>
    IntConst  -> <string>
    Id        -> <string>
```

Tools for Regular Tree Grammars

- Derive from SDF syntax definition

```
$ sdf2rtg -i Example.def -m Example -o Example.rtg
```

- Check the format of a tree

```
$ format-check --rtg Example.rtg
```

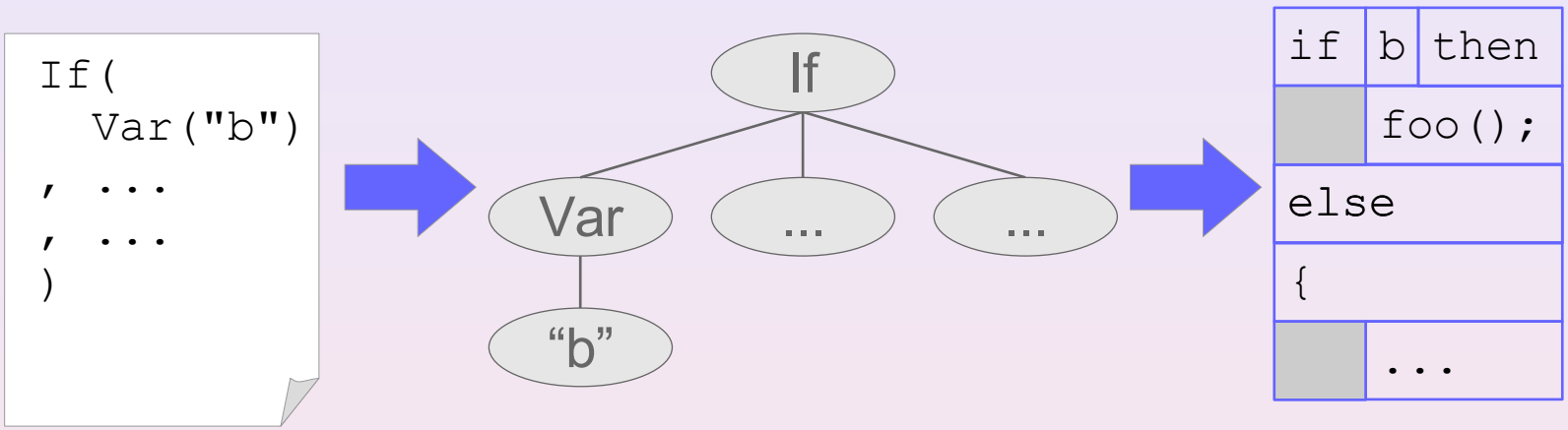
```
martin@logistico:~> format-check --rtg Exp.rtg -i exp3.trm --vis
error: cannot type Int(1)
    inferred types of subterms:
    typed 1 as <int>
error: cannot type Div(1,Var("c"))
    inferred types of subterms:
    typed 1 as <int>
    typed Var("c") as Exp
Plus(
  Mul(Int(1), Var("a"))
, Minus(Var("b"), Div(1, Var("c")))
)
martin@logistico:~>
```

- Generate tools and libraries

```
$ rtg2sig -i Example.rtg -o Example.str
```

Pretty-printing

Code generators and source to source transformation systems need support for pretty-printing.

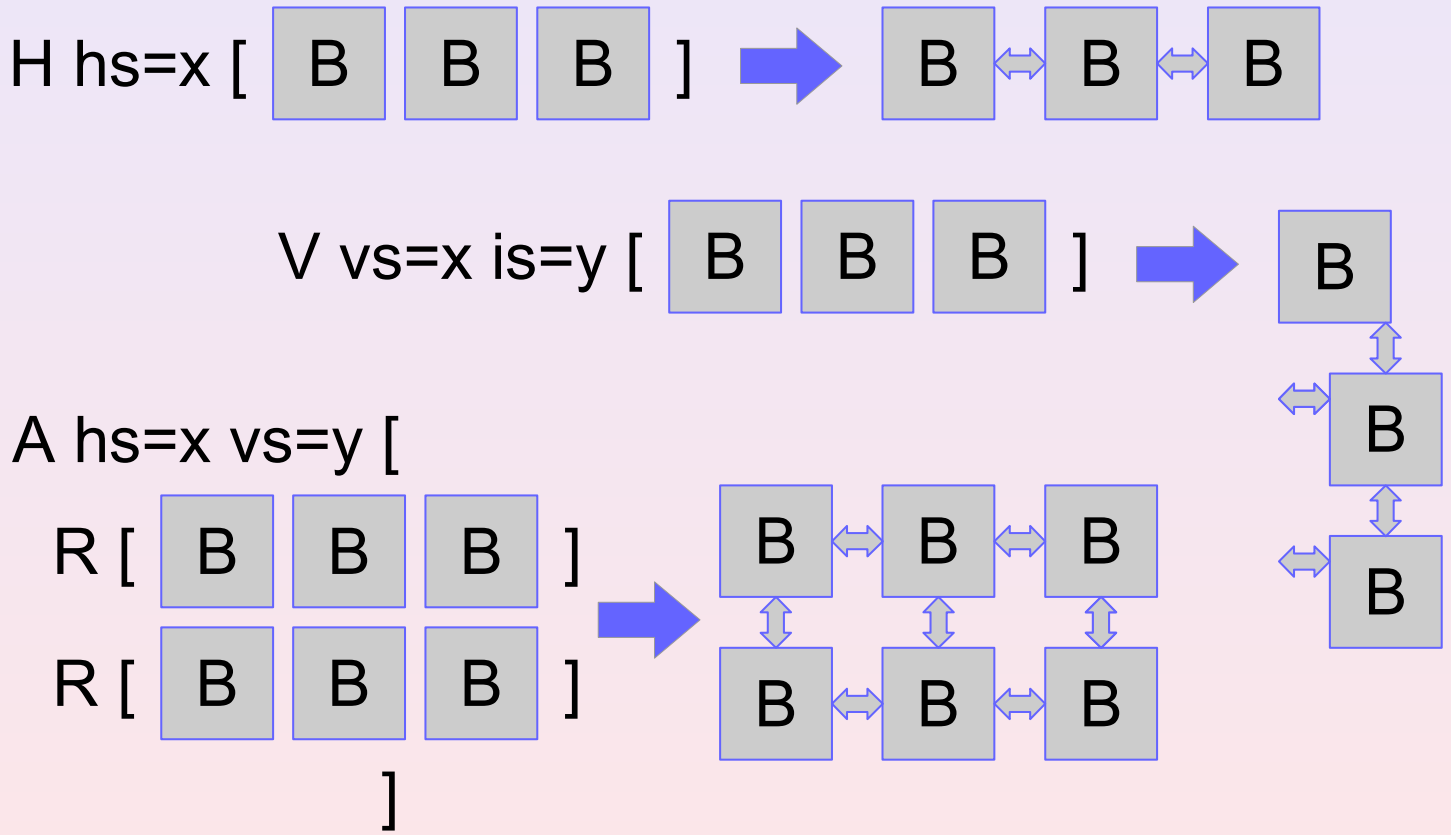


Stratego/XT: GPP (Generic Pretty-Printing)

- Box language
- Pretty-printer generation
- Different back-ends: `abox2text`, `abox2html`, `abox2latex`

Box Language

- Text formatting language
- Options for spacing, indenting
- 'CSS for plain text'



Other boxes: HV, ALT, KW, VAR, NUM, C

Example Box

```
V is=2 [
  H [KW["while"] "a" KW["do"]]
  V [
    V is=2 [
      H hs=1 [KW["if"] "b" KW["then"]]
      H hs=0 ["foo()" ";"]
    ]
    KW["else"]
    V [V is=2 ["{" "..."] "}"]
  ]
]
```

```
while a do
  if b then
    foo();
  else
  {
    ...
  }
```

Pretty-print Tables

- List of pretty-print rules
- Applied by constructor name (`cons` attribute)

Example Pretty-Print Table

```
[
   Var  -- _1,
   Bool -- _1,
   Int  -- _1,
   Mul  -- _1 KW["*"] _2,
   Plus -- _1 KW["+"] _2,
   Min  -- _1 KW["-"] _2,
   Call -- _1 KW["("] _2 KW[")"],
   Call.2:iter-star-sep -- _1 KW[","]
]
```

- `ast2abox` accepts sequence of pretty-print tables
- Tables can be combined and reused

```
$ echo "1 + 2" | sglri -p Ex.tbl | ast2abox -p Ex.pp | abox2text
```

Pretty-printer Generation

- Pretty-print table can be generated from SDF syntax definition (`ppgen`)
  - Complete and correct (usually)
  - Minimal formatting
- Customization by hand for pretty result
  - Tools for consistency checking and patching (`pptable-diff`)
- Parentheses problem: parentheses inserter can be generated from SDF syntax definition (`sdf2parenthesize`).

Transformation Tool Composition

- Components of transformation system are executable tools
- Standardized tool interface
- ATerm exchange format

XTC: Library for Tool Composition

- Abstraction over **tool location**
  - XTC Repository
- Abstractions for **tool invocation**
  - xtc-transform
- Abstraction from **wiring**
  - Management of intermediate files
- Abstractions for **composing tools**

XT Orbit

- **Java**
  - High-quality syntax definition (1.5)
  - Handcrafted pretty-printer (1.5)
  - Disambiguation
  - Type-checker (work in progress)
- **C** (EPITA, France)
  - Syntax definition (C99)
  - Disambiguation
- **Octave**
  - Talk this afternoon
- **Prolog**
  - Syntax definition
  - Embedding of object languages (talk this afternoon)
- **BibTeX**
  - Syntax definition
  - Web services