

Developing SDF3


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Agenda

- SDF Storyline
- SDF3
- SDF4?



Original
SDF

module Language

sorts ID NAT PROGRAM STATEMENT SERIES EXP

lexical syntax

`[\t\n\r]` -> LAYOUT
`[a-z]` `[a-z0-9]*` -> ID
`[0-9]+` -> NAT

context-free syntax

program SERIES	-> PROGRAM	
begin SERIES end	-> SERIES	
{STATEMENT ";"}	-> SERIES	
ID ":=" EXP	-> STATEMENT	
until EXP do SERIES	-> STATEMENT	
if EXP then SERIES else SERIES	-> STATEMENT	
EXP "+" EXP	-> EXP	{left}
EXP "*" EXP	-> EXP	{left}
"(" EXP ")"	-> EXP	{bracket}
ID	-> EXP	
NAT	-> EXP	

priorities

EXP "*" EXP -> EXP > EXP "+" EXP -> EXP

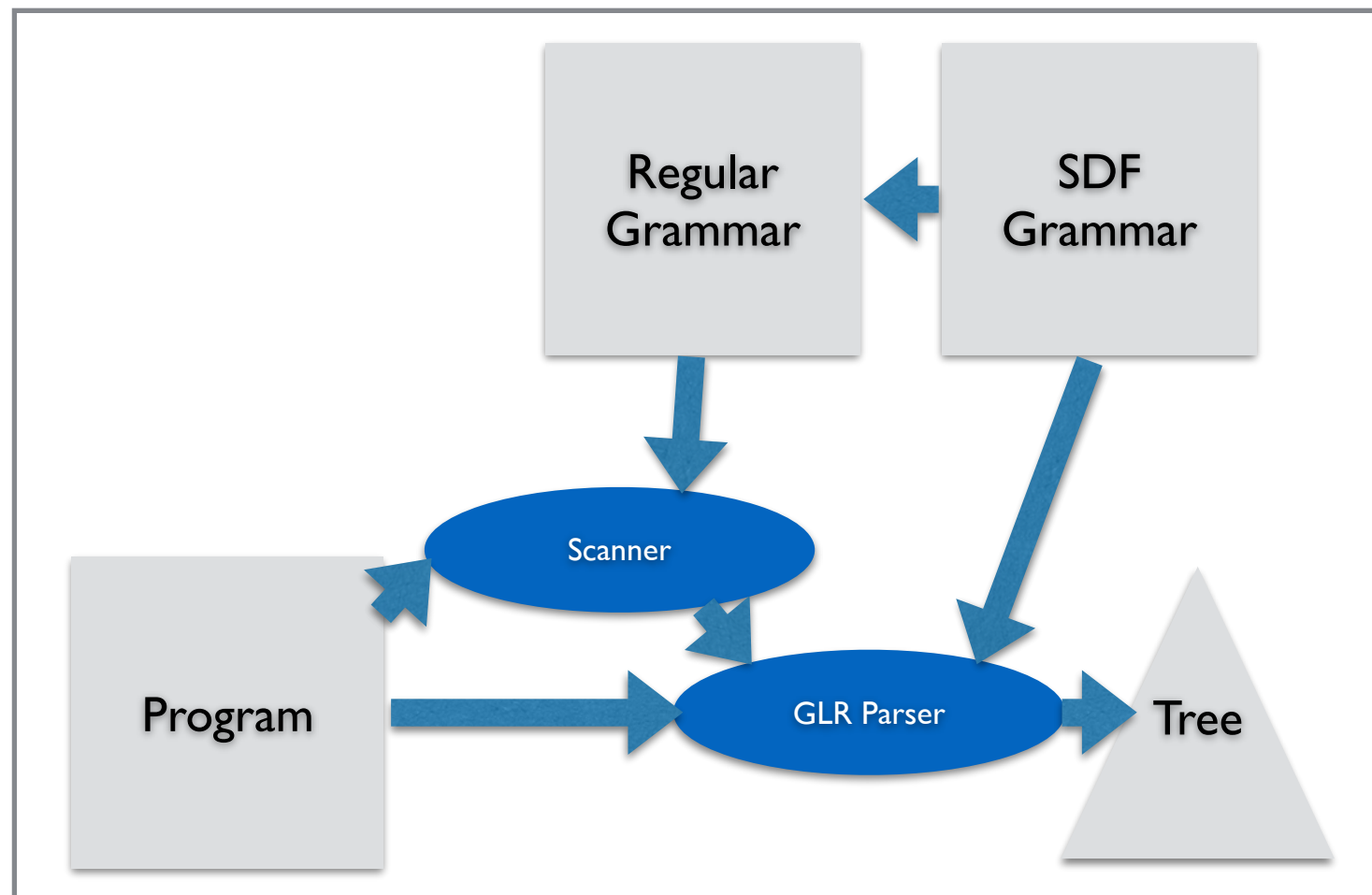
variables

Exp -> EXP
Series -> SERIES

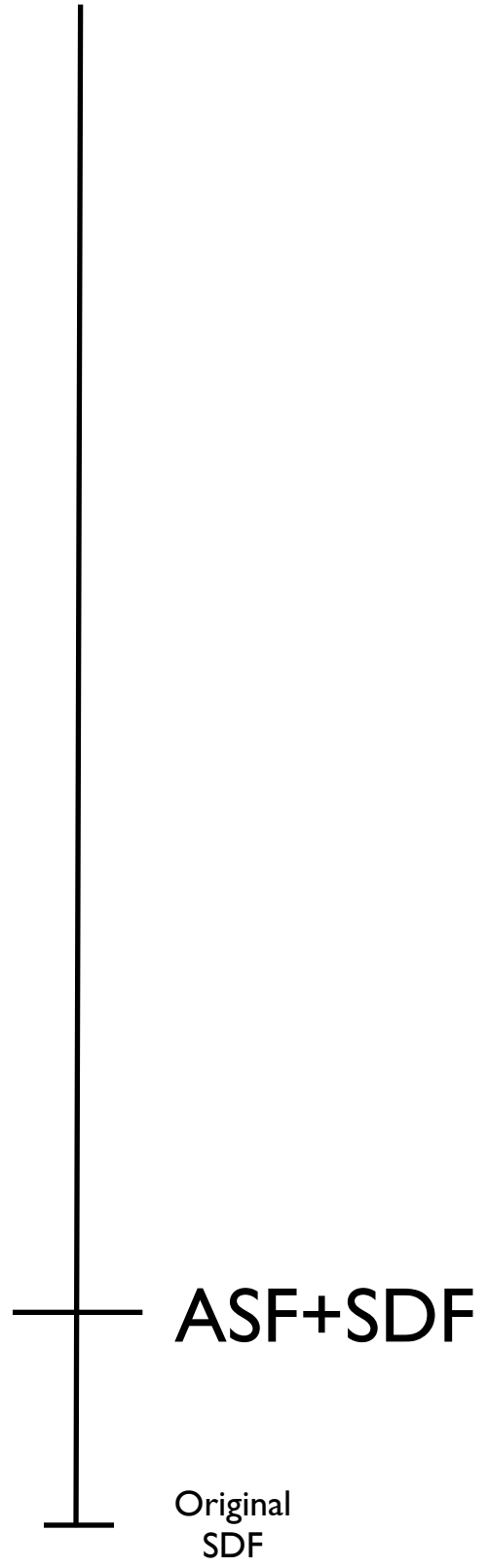
The Syntax Definition Formalism SDF - reference manual.

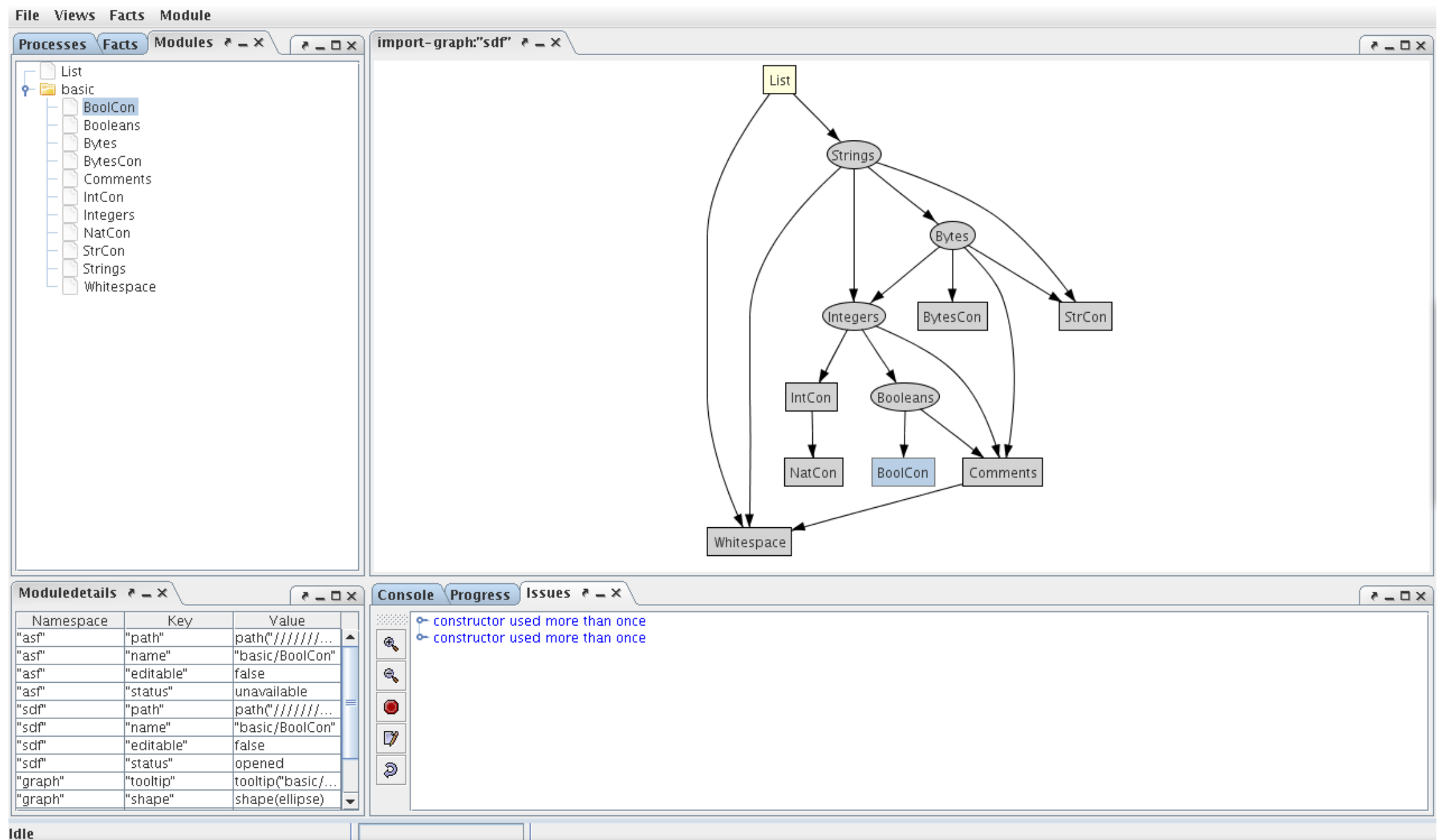
J. Heering, P. R. H. Hendriks, P. Klint, and J. Rekers.

SIGPLAN, 1989.



Lexical and Context-free syntax were not completely separated!

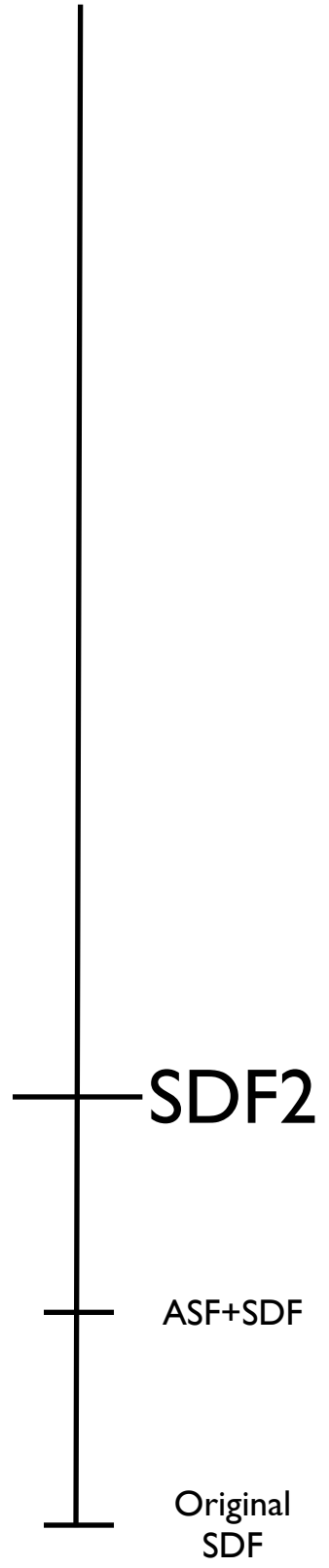


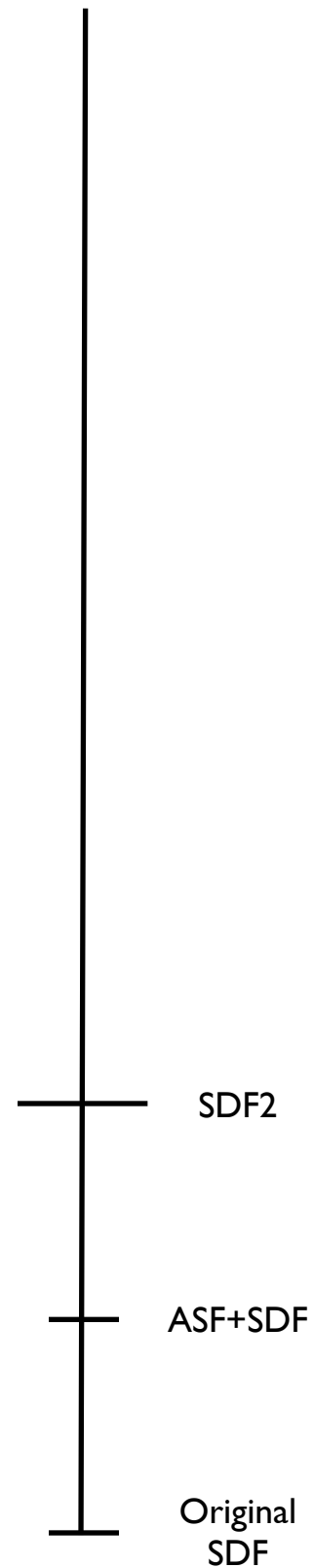


ASF+SDF

Original
SDF

The ASF+SDF Meta-environment.
Arie van Deursen, T. B. Dinesh, Emma van der Meulen.
AMAST, 1993.





```

module Language
exports
  sorts ID NAT Program Statement Series Exp

lexical syntax
  [\t\n\r]      -> LAYOUT
  [a-z] [a-zA-Z0-9]* -> ID
  [0-9]+        -> NAT

lexical restrictions
  LAYOUT -/- [\t\n\r]
  NAT    -/- [0-9]
  ID     -/- [a-zA-Z0-9]

lexical syntax
  "int" -> ID {reject}

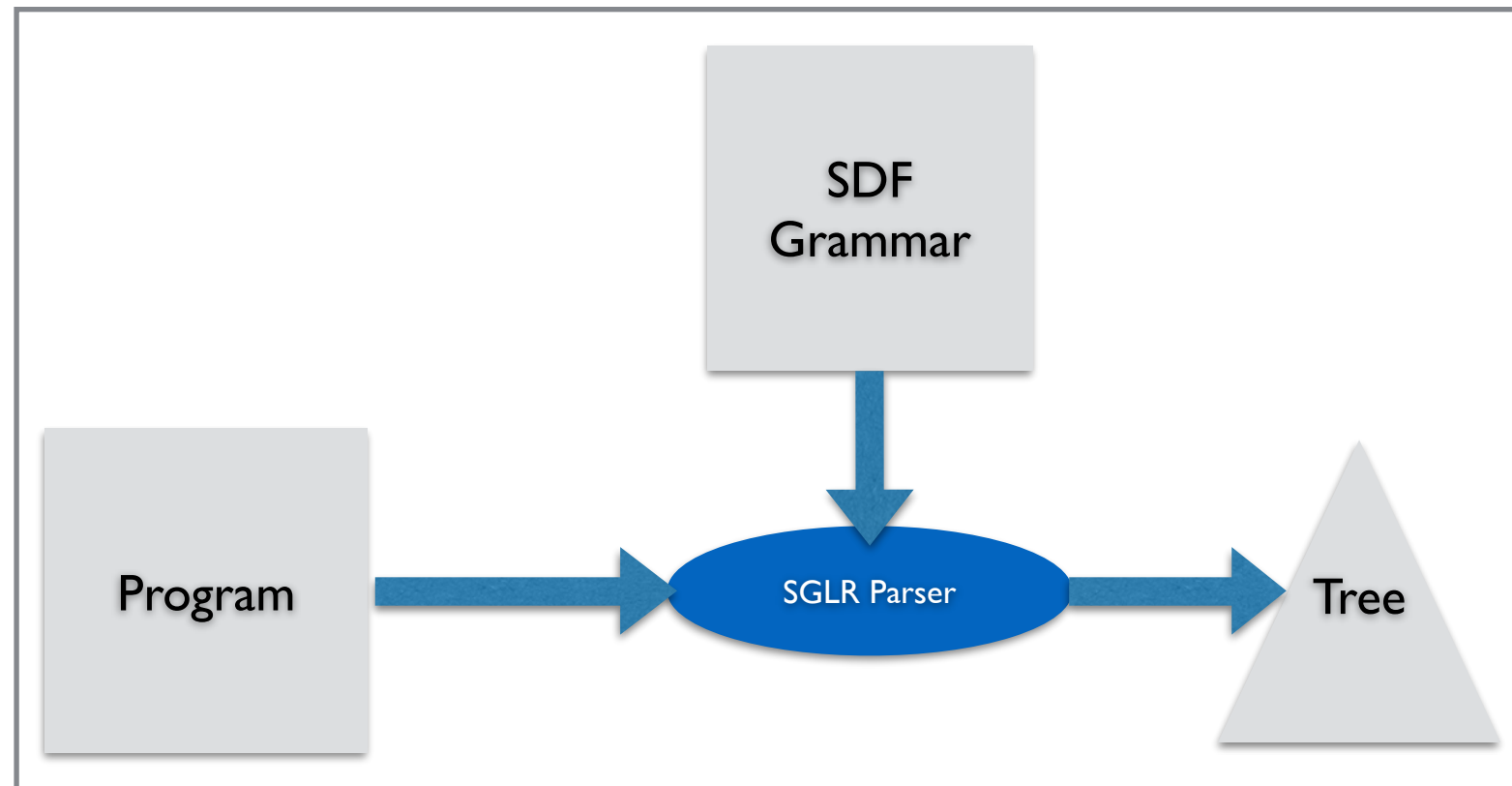
context-free syntax
  "program" Series -> Program
  "begin" Series "end" -> Series
  {Statement ";" }* -> Series
  ID ":@" Exp -> Statement
  "if" Exp "then" Series "else" Series -> Statement
  Exp "+" Exp -> Exp {left}
  Exp "*" Exp -> Exp {left}
  "(" Exp ")" -> Exp {bracket}
  ID -> Exp
  NAT -> Exp

context-free priorities
  Exp "*" Exp -> Exp > Exp "+" Exp -> Exp

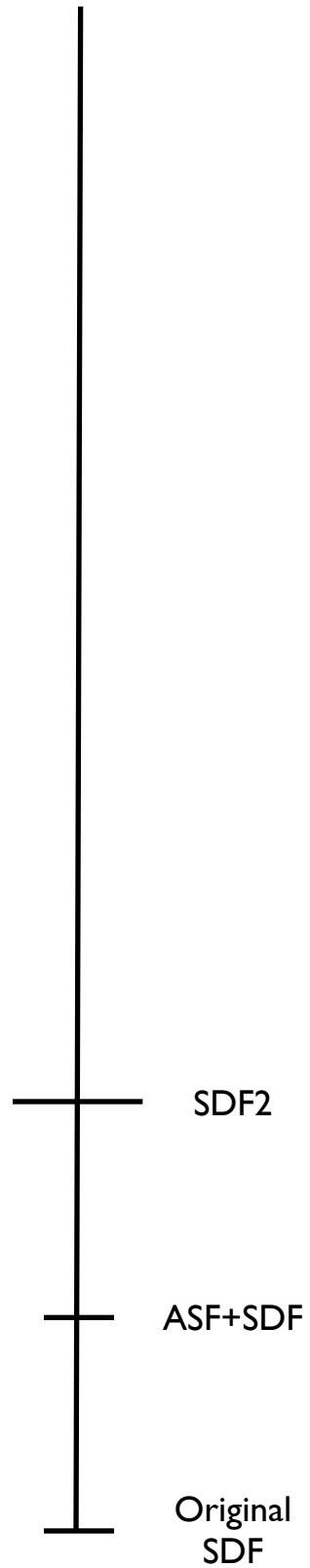
variables
  "Exp" -> Exp
  "Series" -> Series

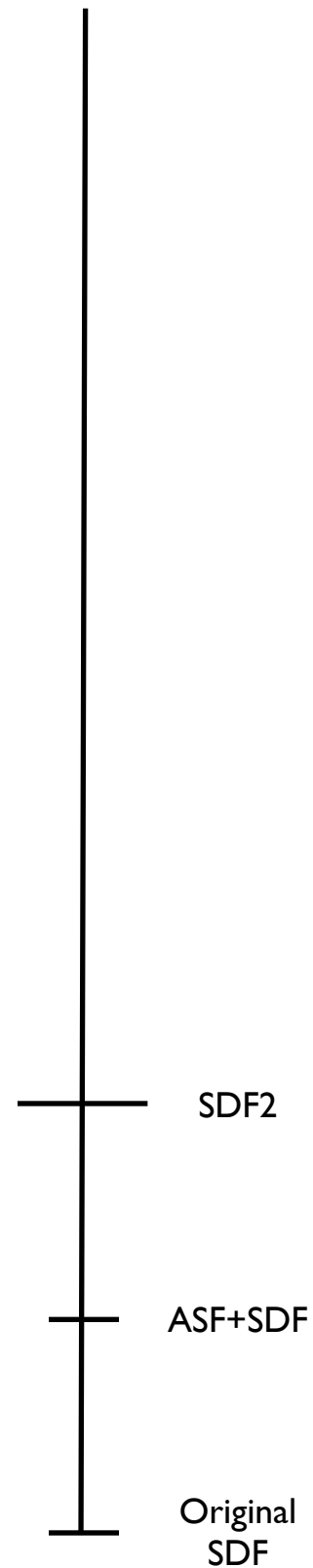
```

Syntax Definition for Language Prototyping.
 E.Visser.
 PhD thesis, University of Amsterdam, 1997.



Crucial for Language Embedding





```

module Language
exports
  sorts ID NAT Program Statement Series Exp

lexical syntax
  [\t\n\r]      -> LAYOUT
  [a-z] [a-zA-Z0-9]* -> ID
  [0-9]+        -> NAT

lexical restrictions
  LAYOUT -/- [\t\n\r]
  NAT    -/- [0-9]
  ID     -/- [a-zA-Z0-9]

lexical syntax
  "int" -> ID {reject}

context-free syntax
  "program" Series      -> Program
  "begin" Series "end"  -> Series
  {Statement ";" }*    -> Series
  ID ":@" Exp          -> Statement
  "if" Exp "then" Series "else" Series -> Statement
  Exp "+" Exp          -> Exp {left}
  Exp "*" Exp          -> Exp {left}
  ID                  -> Exp
  NAT                 -> Exp
  "(" Exp ")"         -> Exp {bracket}

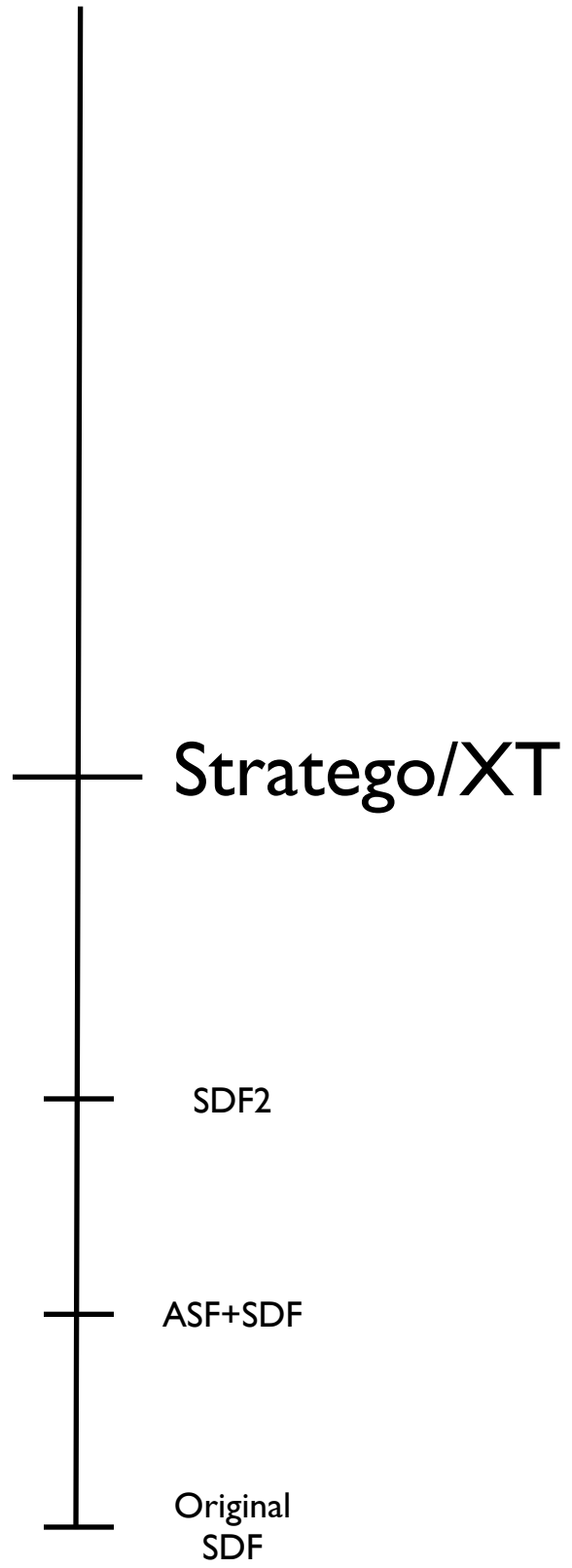
context-free priorities
  Exp "*" Exp -> Exp > Exp "+" Exp -> Exp

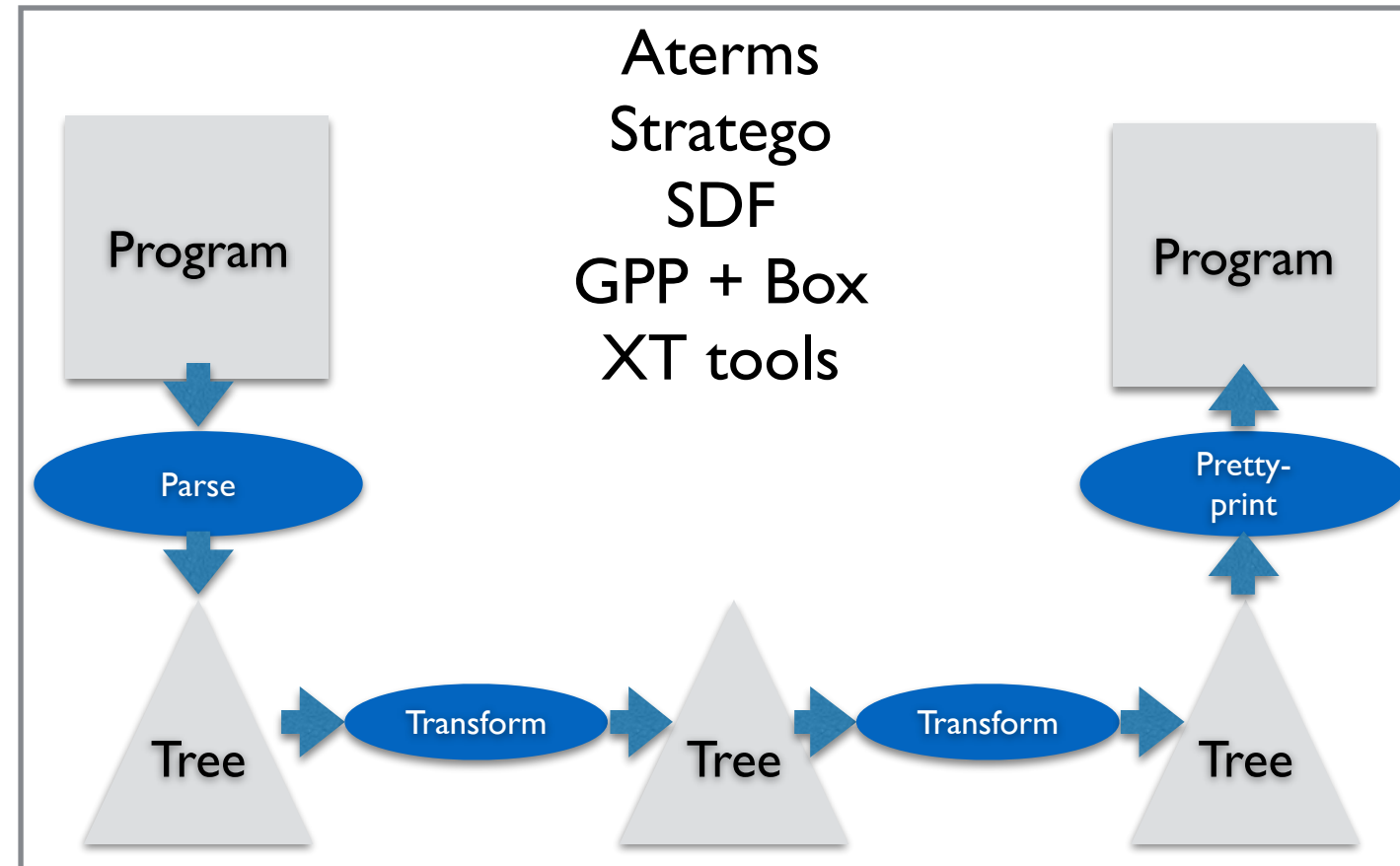
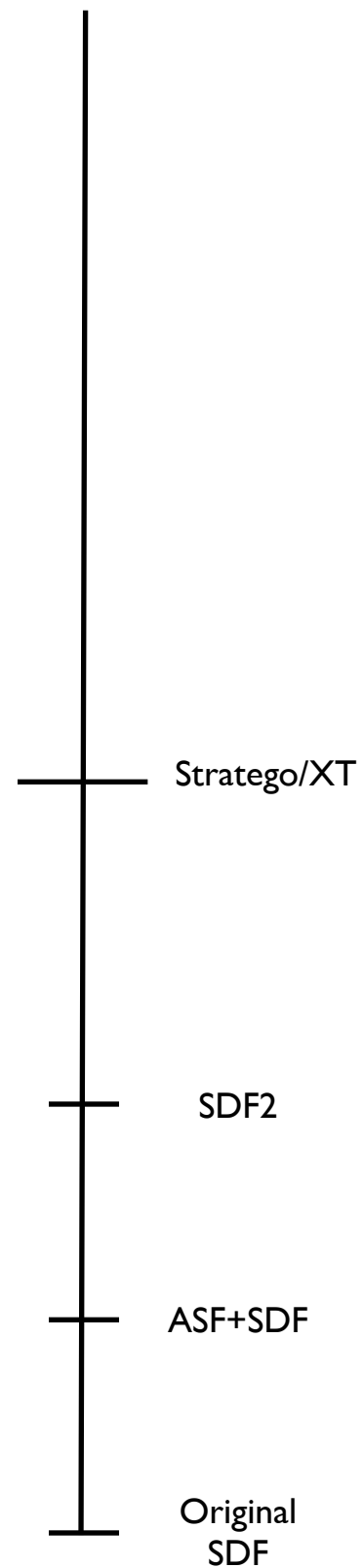
variables
  "Exp" -> Exp
  "Series" -> Series

```

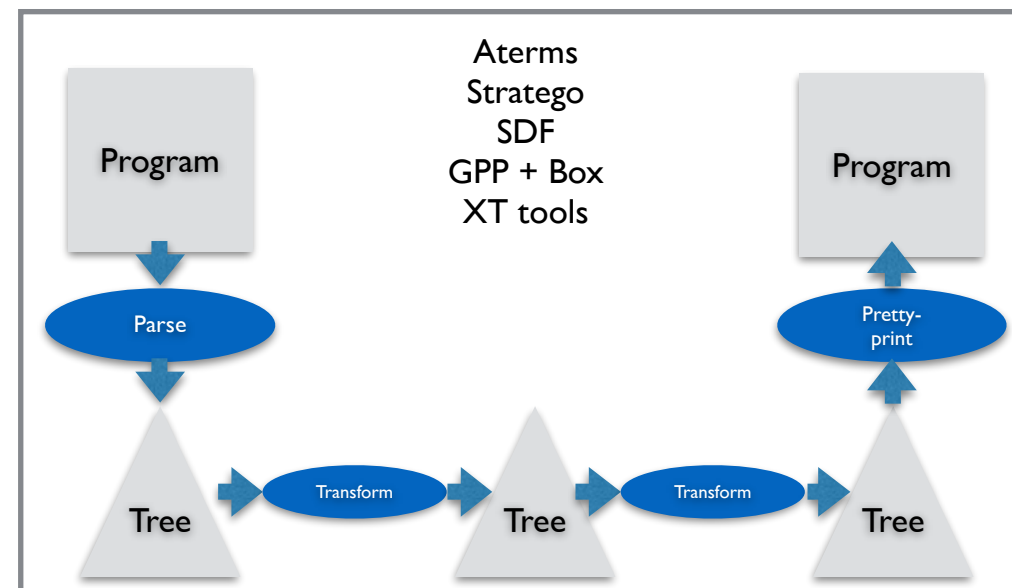
Longest Match

Reserved
Keywords





*Program Transformation with Stratego/XT:
Rules, Strategies, Tools, and Systems in Stratego/XT 0.9.*
Eelco Visser.
Domain-Specific Program Generation, 2003.



- PackSDF
- SDF2RTG
- RTG2SIG
- SDF2Table

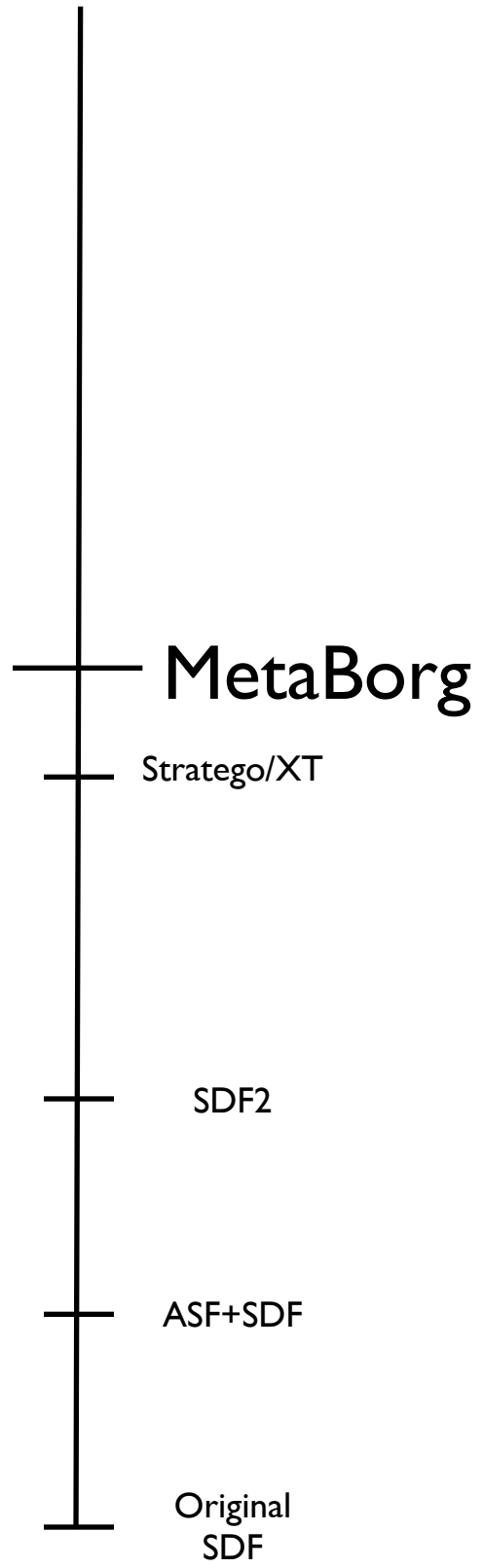
Stratego/XT

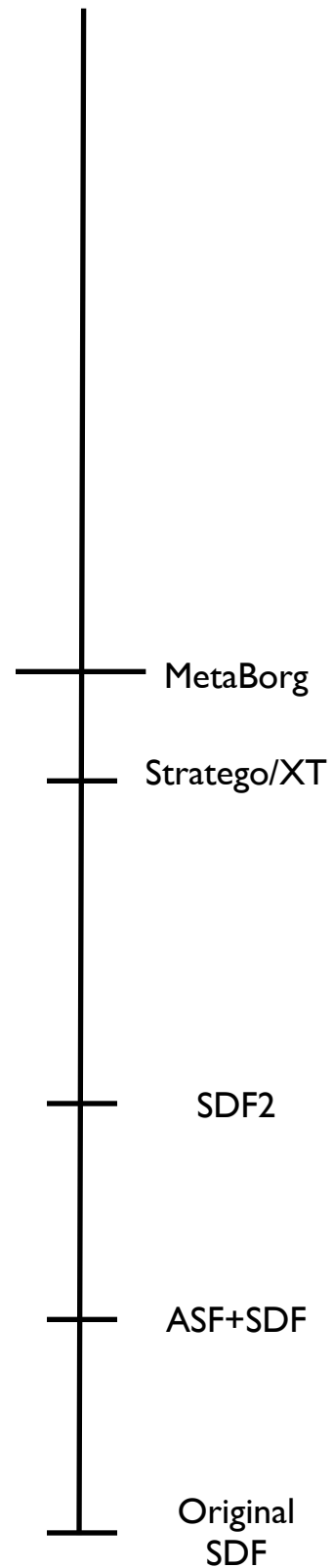
SDF2

ASF+SDF

Original
SDF

*Program Transformation with Stratego/XT:
Rules, Strategies, Tools, and Systems in Stratego/XT 0.9.*
Eelco Visser.
Domain-Specific Program Generation, 2003.





```
module gen-hello-world
imports
  libstratego-lib
  libjava-front

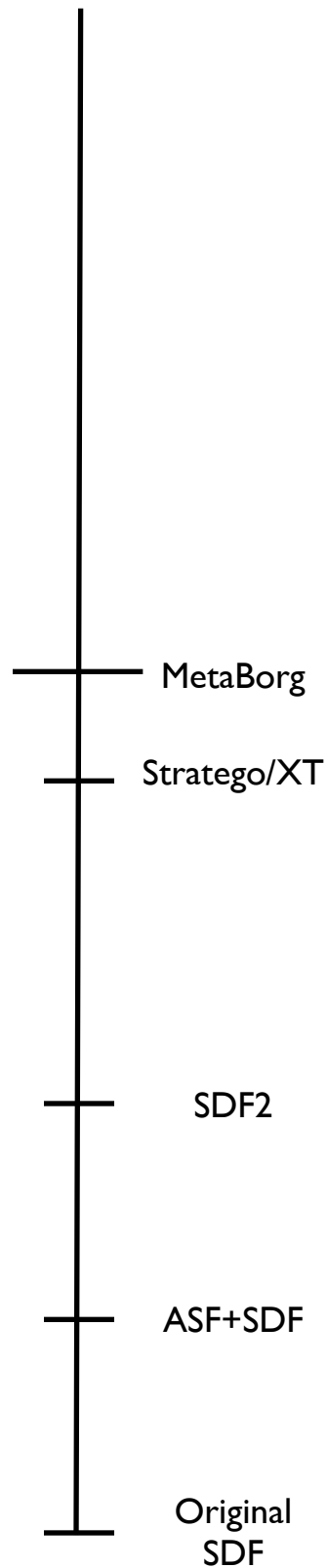
strategies

main =
  output-wrap(generate)

generate =
  !compilation-unit
  |
    public class HelloWorld
    {
      public static void main(String[] ps)
      {
        System.err.println("Hello world!");
      }
    }
  |
```

MetaBorg in Action: Examples of Domain-Specific Language Embedding and Assimilation Using Stratego/XT.

Martin Bravenboer, René de Groot, Eelco Visser.
GTTSE, 2005.



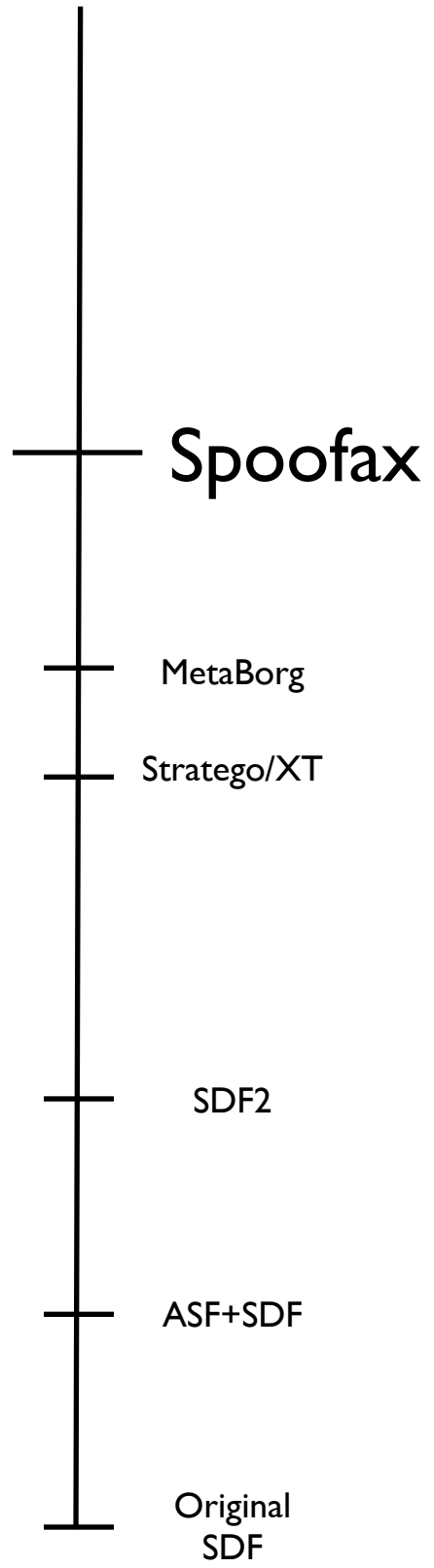
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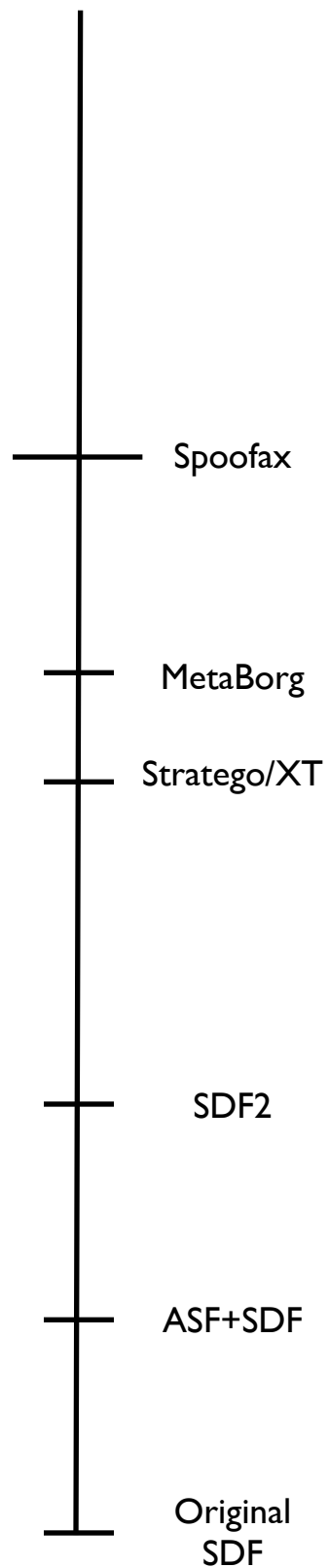
module EmbeddedJava
exports
  context-free syntax
    "e" "[" Expr "]" -> E {cons("ToMetaExpr")}
    "java:expr" "[" Expr "]" -> E {cons("ToMetaExpr")}
    "expr" "[" Expr "]" -> E {cons("ToMetaExpr")}
    "java" "[" Expr "]" -> E {cons("ToMetaExpr")}
    "java:compilation-unit" "[" CompilationUnit "]" -> E {cons("ToMetaExpr")}
    "compilation-unit" "[" CompilationUnit "]" -> E {cons("ToMetaExpr")}
    "java" "[" CompilationUnit "]" -> E {cons("ToMetaExpr")}

```

*MetaBorg in Action: Examples of Domain-Specific Language Embedding
and Assimilation Using Stratego/XT.*

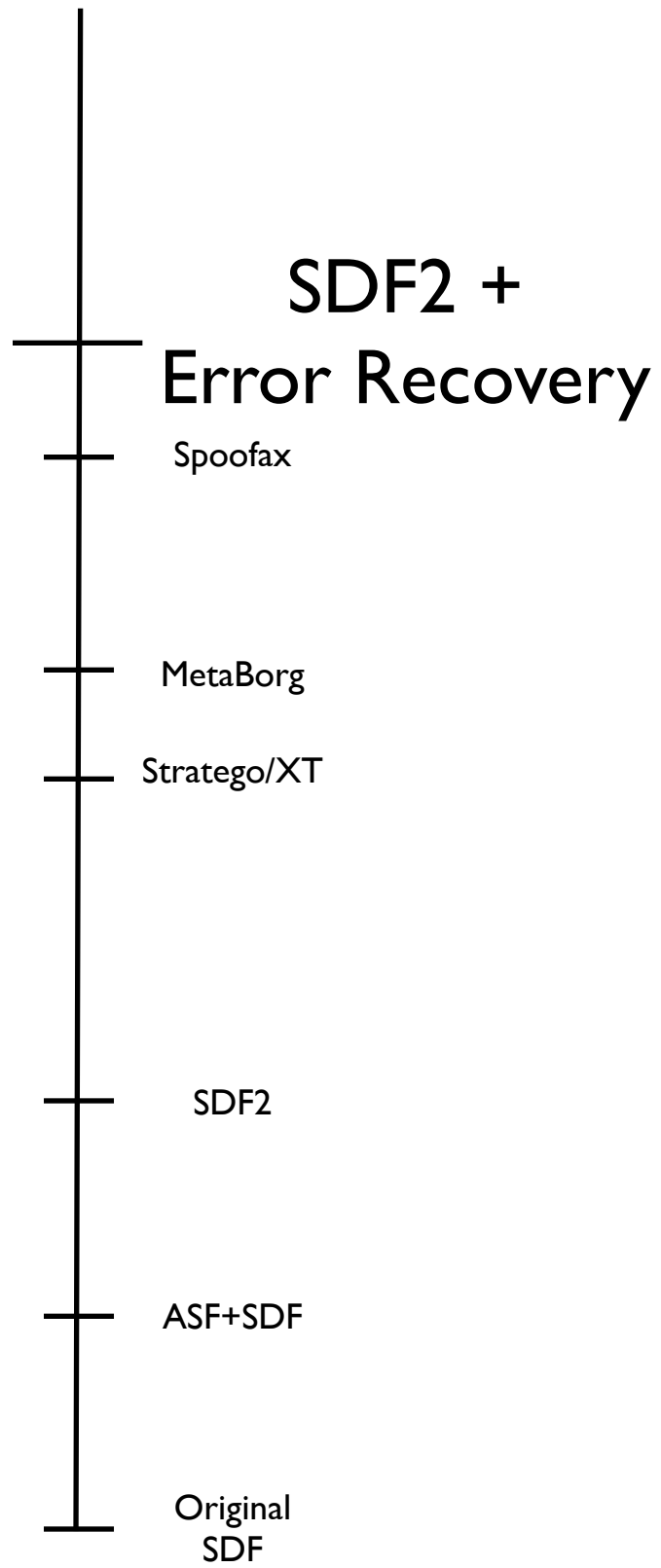
Martin Bravenboer, René de Groot, Eelco Visser.
GTTSE, 2005.

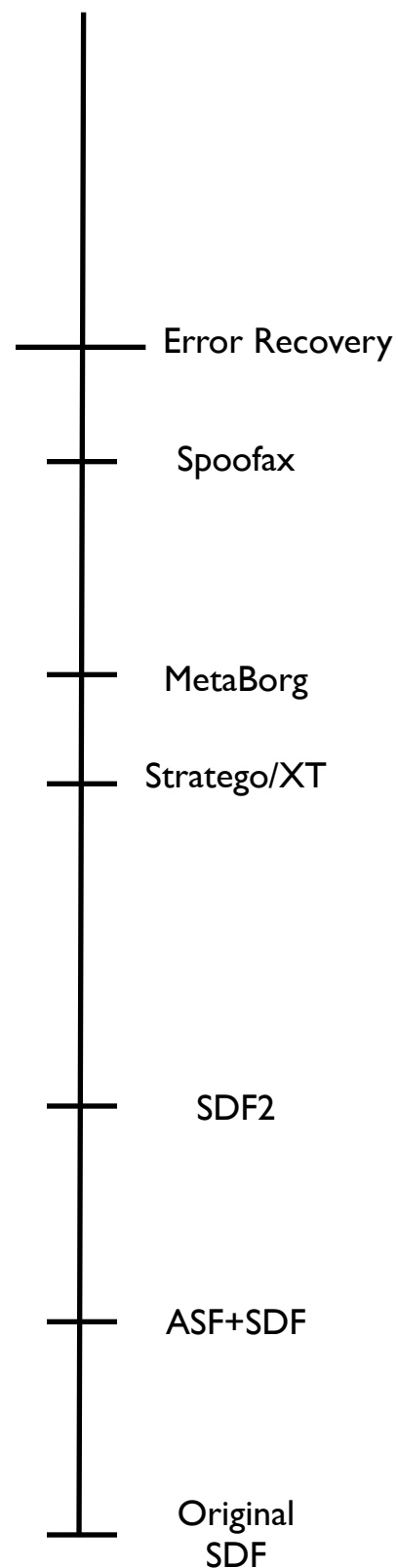




```

EntityLang.sdf
1 module EntityLang
2 imports Common
3
4 exports
5   context-free start-symbols
6     Start
7
8   context-free syntax
9     "module" ID Definition* -> Start {cons("Module")}
10    "entity" ID "{" Property* "}" -> Definition {cons("Entity")}
11    ID ":" Type -> Property {cons("Property")}
12    ID -> Type {cons("Type")}
13    ID "<>"
14
15    INT
16    LAYOUT
17    left:symbol
18    NewLineEOF
19    ns@symbol
20    Property
21    Start
22    STRING
23    StringChar
24    symbol
25    Type
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```

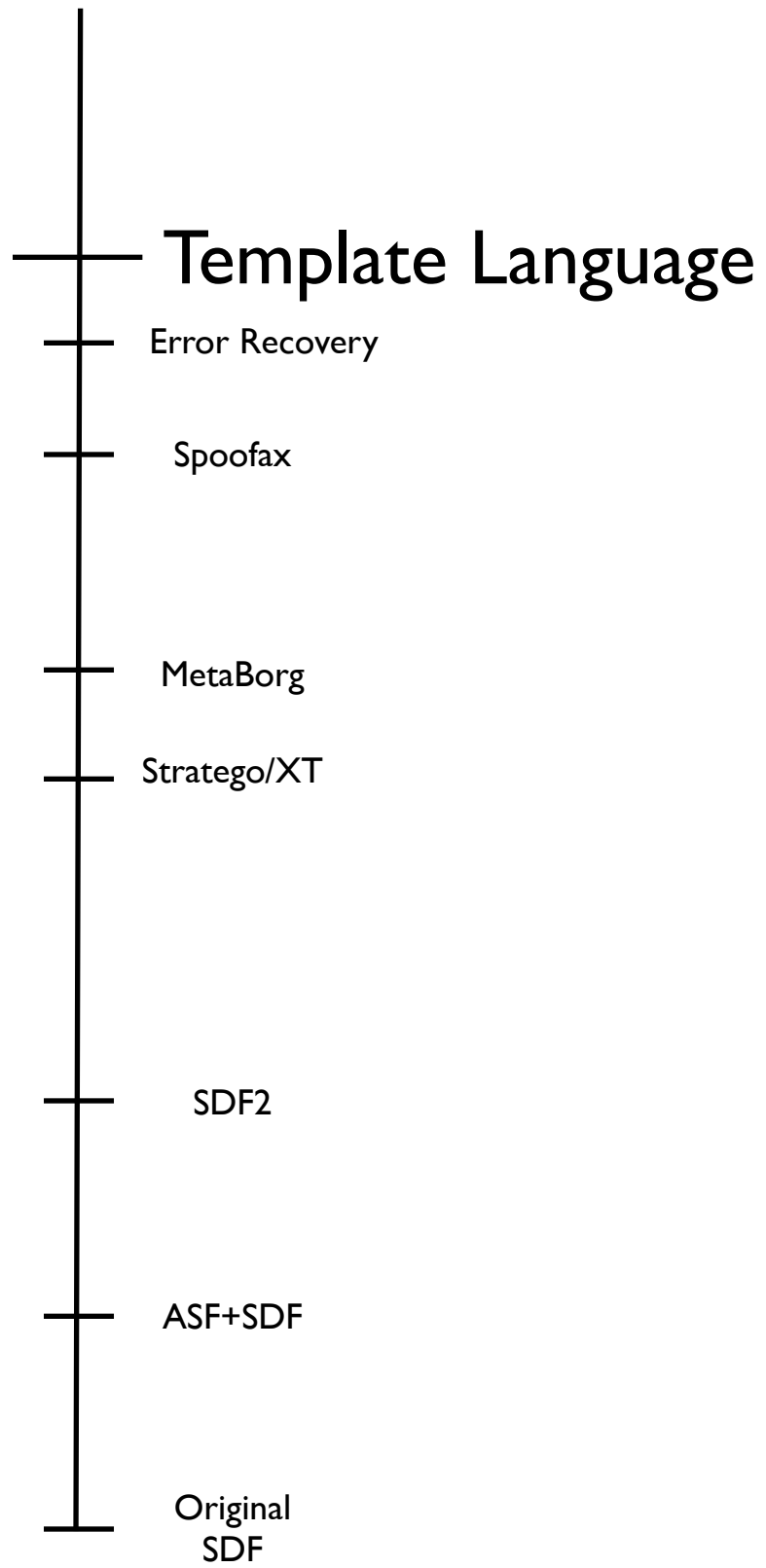
16 Statement.IfThenElse = <
17     if <Exp>
18     then <Series>
19     else
20     <Serie>>
21 Statement.Until      = <
22     until <Exp>
23     do <Series>>
24 Exp                 = <( <Exp> )>           {bracket}
25 Exp.Sub             = <<Exp> - <Exp>>       {non-assoc}
26 Exp.Mul             = <<Exp> * <Exp>>       {left}
27 Exp.Add             = Exp "+" Exp         {left}
28 Exp.Div             = Exp "/" Exp         {non-assoc}
29 Exp                 = ID
30 Exp                 = NAT
31 Type                :=

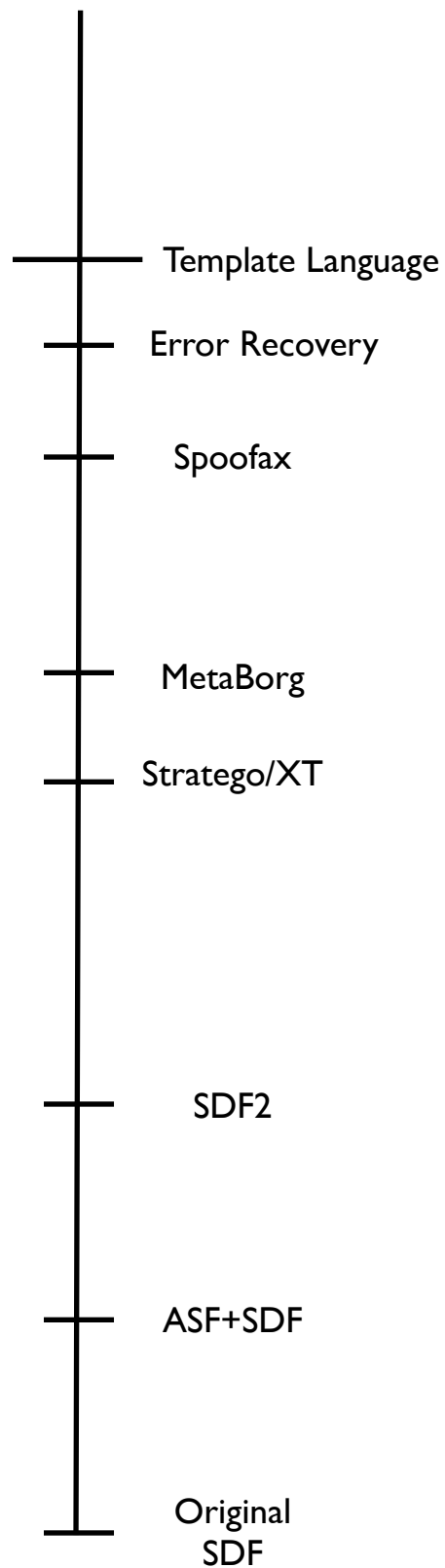
```

Unresolved reference to sort
'Serie'

Syntax error, not expected here:
'.'

Natural and flexible error recovery for generated modular language environments.
M. de Jonge, L. C. L. Kats, E. Visser, and E. Söderberg.
TOPLAS, 2012.





templates

```
Start.Module = <
  module <ID>

  <{Definition "\n\n"}*>
>

Definition.Entity = <
  entity <ID> {
    <{Property "\n"}*>
  }
>

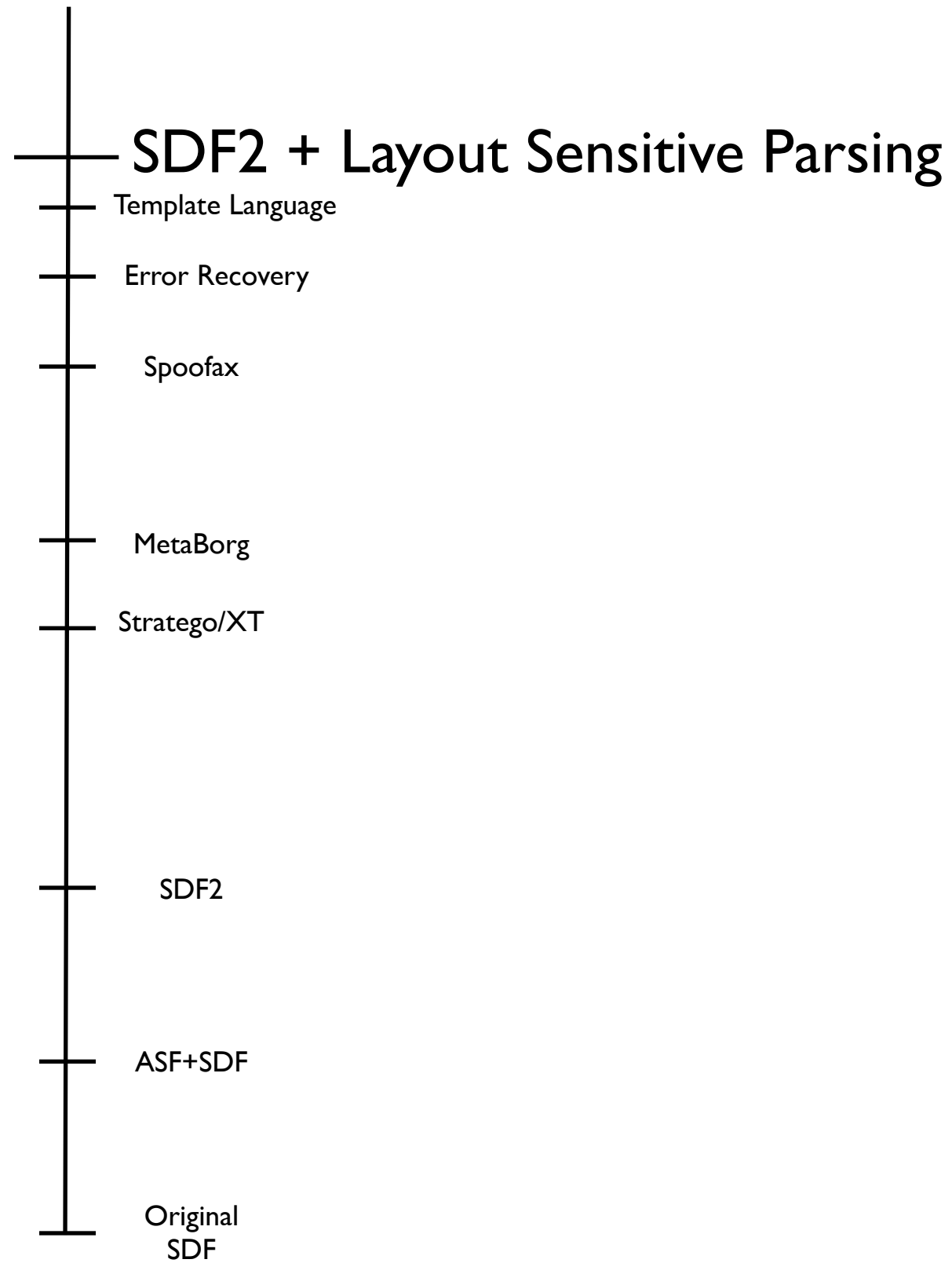
Property.Property = <<ID> : <Type>>

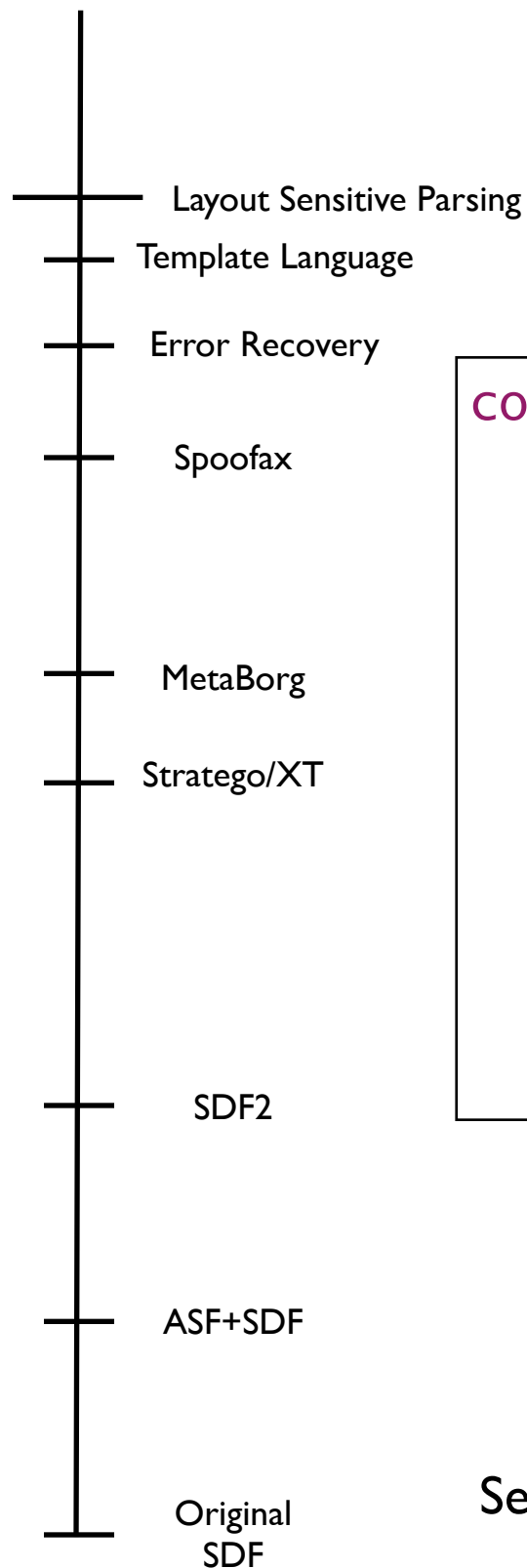
Type.Type = <<ID>>
```

template options

```
tokenize : “:{}”
keyword  -/- [a-zA-Z0-9\_ ]
newlines : separating
```

Declarative specification of template-based textual editors.
T. Vollebregt, L. C. L. Kats, and E. Visser.
LDTA, 2012.





context-free syntax

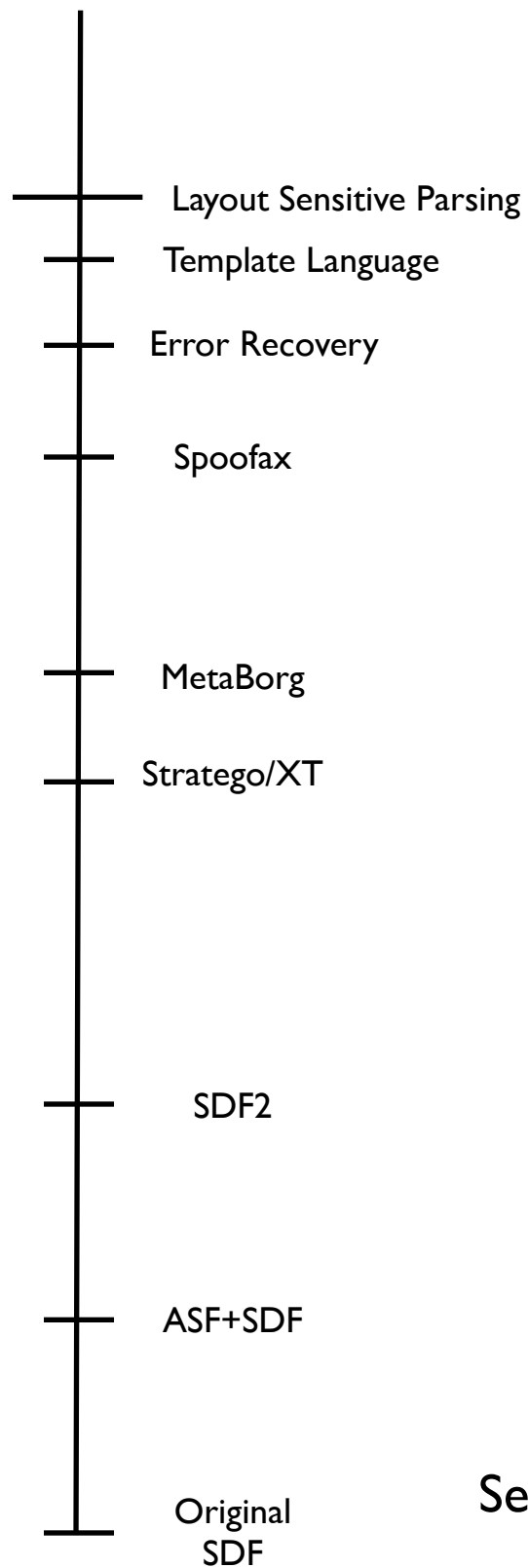
```

Stm          -> Impl {layout("1.first.col < 1.left.col")}
Impl          -> Impls
Impl Impls    -> Impls {cons("StmSeq"),
                     layout("1.first.col == 2.first.col")}

Stm          -> Expls
Stm ";" Expls -> Expls {cons("StmSeq")}
Impls         -> Stms {cons("Stms")}
"{" Expls "}" -> Stms {cons("Stms"), ignore-layout}
"do" Stms     -> Exp {cons("Do"), longest-match}
  
```

Layout-Sensitive Generalized Parsing.

Sebastian Erdweg, Tillmann Rendel, Christian Kästner, Klaus Ostermann.
SLE 2012.



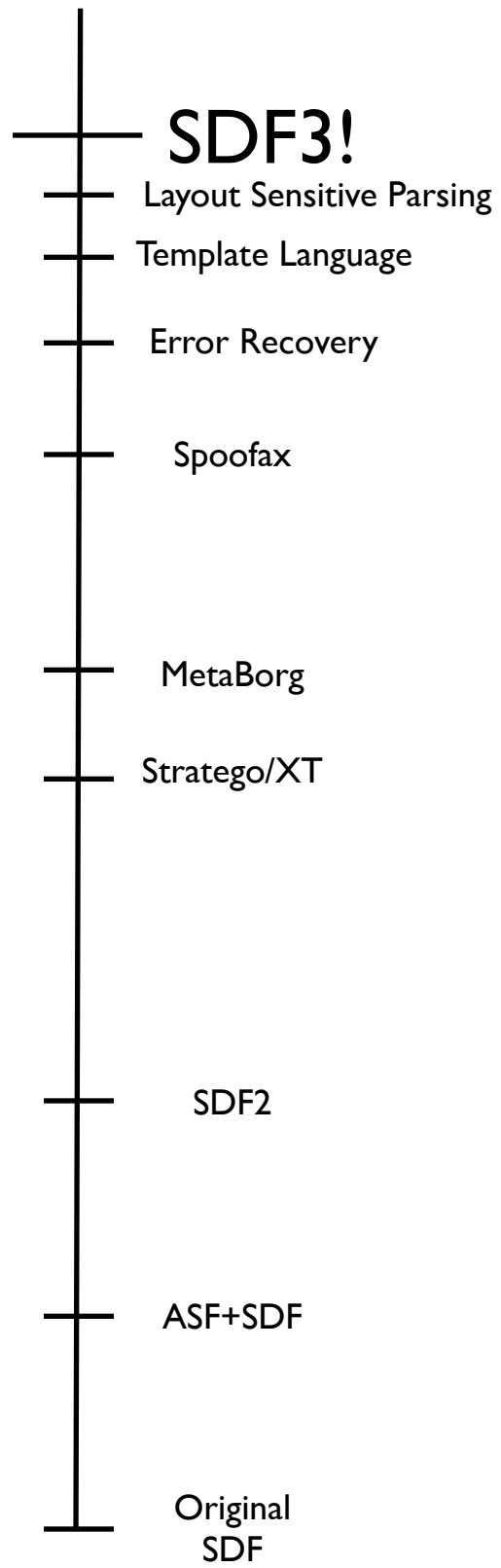
```
main = do print 16
        print (11 + 12)
        print 42
```

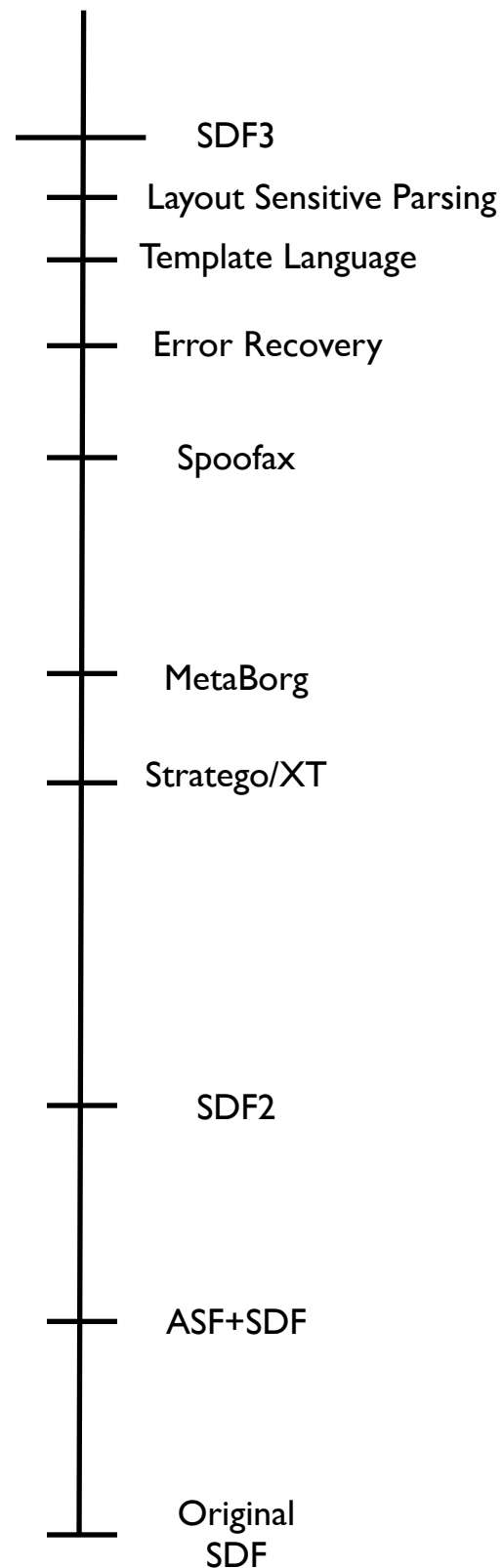
```
main = do print 16
        print (11 + 12)
        → print 42
```

```
main = do print 16
        print (11 + 12)
        print 42
```

Layout-Sensitive Generalized Parsing.

Sebastian Erdweg, Tillmann Rendel, Christian Kästner, Klaus Ostermann.
SLE 2012.





module Language

context-free syntax

```

Program.Program      = <program
                      <Series>>

Series.Block         = <begin
                      <Series>
                      end>

Series.Statements    = <<{Statement ";" }*>>
Statement.Assign     = <<ID> := <Exp>>
Statement.Until      = <until <Exp>
                      do
                      <Series>>

Statement.IfThenElse = <if <Exp> then
                      <Series>
                      else
                      <Series>>

Exp.Plus             = <<Exp> + <Exp>> {left}
Exp.Mul              = <<Exp> * <Exp>> {left}
Exp.Var              = ID
Exp.Int              = NAT
Exp                  = <(<Exp>)> {bracket}

```

context-free priorities

Exp.Mul > Exp.Plus

L. E. S. Amorim, G. Wachsmuth and Eelco Visser.
Developing SDF3.
 Parsing@SLE, 2014.

SDF3

Template Productions

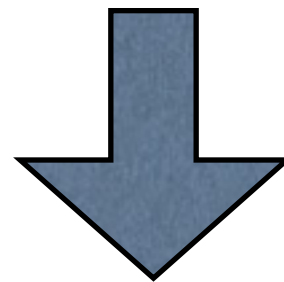
context-free syntax

Program.Program	=	<program <Series>>
Series.Block	=	<begin <Series> end>
Series.Statements	=	<<{Statement ";" }*>>
Statement.Assign	=	<<ID> := <Exp>>
Statement.IfThenElse	=	<if <Exp> then <Series> else <Series>>
Statement.Until	=	<until <Exp> do <Series>>

SDF3

SDF2 Constructors

"if" Exp "then" Series "else" Series	-> Statement	{cons("IfThenElse")}
Exp "+" Exp	-> Exp	{cons("Plus"), left}
Exp "*" Exp	-> Exp	{cons("Mul"), left}
ID	-> Exp	{cons("Var")}
NAT	-> Exp	{cons("Int")}



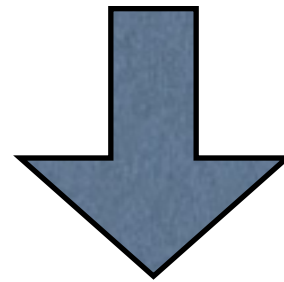
Signatures

```
signature
constructors
  IfThenElse : Exp * Series * Series -> Statement
  Plus       : Exp * Exp          -> Exp
  Mul        : Exp * Exp          -> Exp
  Var        : ID                 -> Exp
  Int        : NAT                -> Exp
```

SDF3

SDF2 Constructors

"if" Exp "then" Series "else" Series	-> Statement	{cons("IfThenElse")}
Exp "+" Exp	-> Exp	{cons("Plus"), left}
Exp "*" Exp	-> Exp	{cons("Mul"), left}
ID	-> Exp	{cons("Var")}
NAT	-> Exp	{cons("Int")}



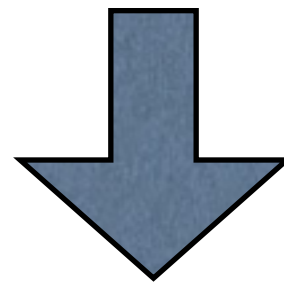
SDF3 Constructors

Statement. <u>IfThenElse</u>	= <if <Exp> then <Series> else <Series>>
Exp. <u>Plus</u>	= <<Exp> + <Exp>> {left}
Exp. <u>Mul</u>	= <<Exp> * <Exp>> {left}
Exp. <u>Var</u>	= ID
Exp. <u>Int</u>	= NAT

SDF3

SDF2 Reductive Productions

"if" Exp "then" Series "else" Series	-> Statement	{cons("IfThenElse")}
Exp "+" Exp	-> Exp	{cons("Plus"), left}
Exp "*" Exp	-> Exp	{cons("Mul"), left}
ID	-> Exp	{cons("Var")}
NAT	-> Exp	{cons("Int")}



SDF3 Productive Productions

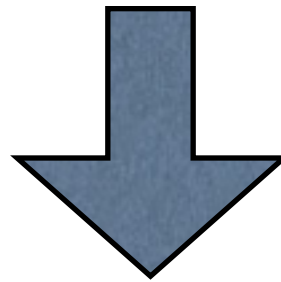
Statement.IfThenElse	=	<if <Exp> then <Series> else <Series>>
Exp.Plus	=	Exp "+" Exp {left}
Exp.Mul	=	Exp "*" Exp {left}
Exp.Var	=	ID
Exp.Int	=	NAT

SDF3

SDF2 Priorities

context-free priorities

Exp "*" Exp -> Exp > Exp "+" Exp -> Exp



SDF3 Priority Shorthands

context-free priorities

Exp.Mul > Exp.Plus

Implementation

SDF3 in SDF3

```
Grammar.ContextFreeSyntax = <
  context-free syntax

  <{GeneralProduction "\n"}*>

  > {prefer}

Productions      = <<list:{Production "\n"}*>>
Production.Prod  = <<Symbols> -\> <result:Symbol> <Attributes>> {deprecated("Use productive form")}

GeneralProduction = <<SdfProduction>>
GeneralProduction = <<TemplateProduction>> {prefer}

SdfProduction.SdfProduction      = <<SymbolDef> = <RHS> <Attributes>>
SdfProduction.SdfProductionWithCons = <<SortCons> = <RHS> <Attributes>>
RHS.Rhs                          = <<Symbols>>

TemplateProduction.TemplateProduction = <<SymbolDef> = <Template> <Attributes>>
```

Static Analysis - Name Binding

namespaces

Module Sort Constructor

binding rules

Module(Unparameterized(m), i*, s*):

 defines Module m

 scopes Sort, Constructor

Module(Unparameterized(m)):

 imports Sort, Constructor from Module m

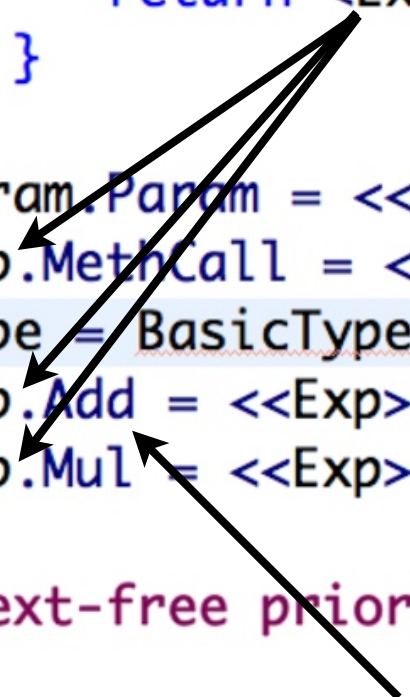
SdfProductionWithCons(SortCons(SortDef(s), Constructor(c)), rhs, attrs):

 defines non-unique Sort s

 defines unique Constructor c

Name Analysis

```
1 module Example
2
3 imports Common
4
5 context-free syntax
6
7 Method.Method = <
8   <Type> <ID>(<{Param " ", "*"}>) {
9     return <Exp>;
10  }
11 >
12 Param.Param = <<Type> <ID>>
13 Exp.MethCall = <<Exp>.<ID>(<{Exp " ", "*"}>)>
14 Type = BaseType
15 Exp.Add = <<Exp> + <Exp>>
16 Exp.Mul = <<Exp> * <Exp>>
17
18 context-free priorities
19
20 Exp.Mul > Exp.Add
```



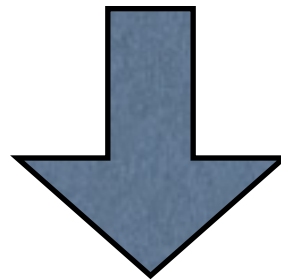
Unresolved reference to sort 'BasicType'

Type Analysis - Stratego

```
create-type-task(lctx) :  
  Rhs(symbols*) -> <task-create-id(lctx,[t])> t  
  where  
    symbols'* := <filter(is-typable)> symbols*;  
    t         := <type-task(lctx)> symbols'*  
  
create-type-task(lctx) :  
  Sort(s) -> <task-create-id(lctx,[t])> t  
  where  
    t' := <type-lookup(lctx)> s;
```

Type Analysis

```
Statement.IfThenElse = <if <Exp> then
                        <Series>
                        else
                        <Series>>
Exp.Plus              = Exp "+" Exp {left}
Exp.Mul               = Exp "*" Exp {left}
Exp.Var               = ID
Exp.Int               = NAT
```



signature

constructors

```
IfThenElse : Exp * Series * Series -> Statement
Plus       : Exp * Exp           -> Exp
Mul        : Exp * Exp           -> Exp
Var        : ID                  -> Exp
Int        : NAT                  -> Exp
```

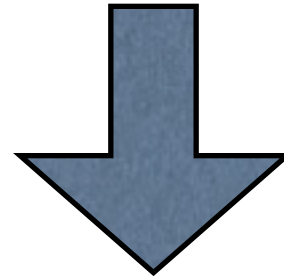

Code Generation

- Content Completion
- Pretty-printer
- Signatures
- SDF2 grammar

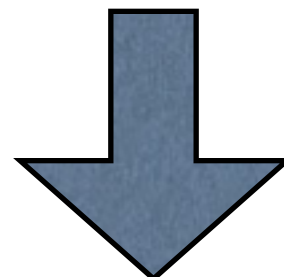
```
▼ src-gen
  ▼ completions
    ● Example-esv.esv
  ▼ pp
    ● Example-pp.str
  ▼ signatures
    ● Example-sig.str
  ▼ syntax
    ● Example.sdf
```

Content Completion

```
Statement.IfThenElse      = <if <Exp> then  
                           <Series>  
                           else  
                           <Series>>
```



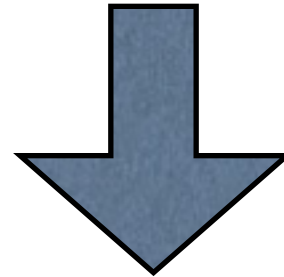
```
completion template Statement : "if Exp then Series else Series" =  
  "if " <Exp:Exp> " then " <Series:Series> " else " <Series:Series>
```



```
example.ent ✕  
1 program  
2 begin  
3   if  
4   end if Exp then Series else Series if Exp then Series else Series
```

Pretty-printer

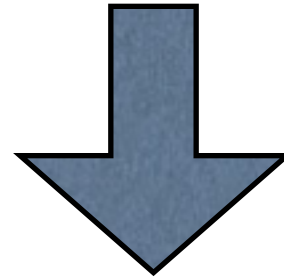
```
Statement.IfThenElse      = <if <Exp> then
                           <Series>
                           else
                           <Series>>
```



```
prettyprint-Statement :
  IfThenElse(t0__, t1__, t2__) -> [ H(
                                   [SOpt(HS(), "0")]
                                   , [ S("if ")
                                       , t0__'
                                       , S(" then")
                                   ]
                                   )
    , t1__'
    , H(
        [SOpt(HS(), "0")]
        , [S("else")]
      )
    , t2__'
  ]
  with t0__' := <pp-one-Z(prettyprint-Exp)> t0__
  with t1__' := <pp-indent(l"2")> [<pp-one-Z(prettyprint-Series)> t1__]
  with t2__' := <pp-indent(l"2")> [<pp-one-Z(prettyprint-Series)> t2__]
```

Pretty-printer

```
Statement.IfThenElse      = <if <Exp> then  
                           <Series>  
                           else  
                           <Series>>
```



example.exe

```
1 program begin if x then  
2 x := 1 else x := x * 2 end
```

example.pp.exe

```
1 program  
2 begin  
3   if x then  
4     x := 1  
5   else  
6     x := x * 2  
7 end
```

Open Issues and Limitations

SDF4?

SDF3

Layout Sensitive Parsing

Template Language

Error Recovery

Spoofax

MetaBorg

Stratego/XT

SDF2

ASF+SDF

Original
SDF

- Parametrized modules
- Language-specific layout
- Layout constraints
- Priorities cannot model all disambiguation policies
- Normalisation of SDF3 definitions is still done through a translation to SDF2

Parametrized Modules

```
module languages/java/EmbeddedJava[E]
imports
  languages/java-15/Main
exports
  %%%
  %% Quotations for Expressions
  %%%
  context-free syntax
    "e" " | [" Expr "]" | " -> E {cons("ToMetaExpr")}
    "java:expr" " | [" Expr "]" | " -> E {cons("ToMetaExpr")}
    "expr" " | [" Expr "]" | " -> E {cons("ToMetaExpr")}
    "java" " | [" Expr "]" | " -> E {cons("ToMetaExpr")}
    " " " | [" Expr "]" | " -> E {cons("ToMetaExpr")}
    "var-init" " | [" VarInit "]" | " -> E {cons("ToMetaExpr")}
```

Language-specific Layout

```
strategies

// Hello World
%% Class Generator
generate =
    !compilation-unit | [
        // Hello World
        %% Class
        public class HelloWorld
        {
            public static void main(String[] ps)
            {
                System.err.println("Hello world!");
            }
        }
    ] |
```


Layout Constraints

context-free syntax

<u>Stm</u>	-> Impl { layout ("1.first.col < 1.left.col")}
Impl	-> Impls
Impl Impls	-> Impls { cons ("StmSeq"), layout ("1.first.col == 2.first.col")}
<u>Stm</u>	-> Expls
<u>Stm</u> ";" Expls	-> Expls { cons ("StmSeq")}
Impls	-> Stms { cons ("Stms")}
"{" Expls "}"	-> Stms { cons ("Stms"), ignore-layout }
"do" Stms	-> Exp { cons ("Do"), longest-match}

SDF Priorities

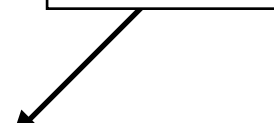
x + if y then z + a



x + if y then (z + a)

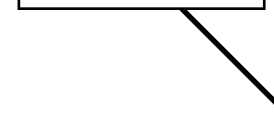
Plus(Var("x"), If(Var("y"), Plus(Var("z"), Var("a"))))

if > "+"



x + (if y then z) + a

"+" > if



Plus(Var("x"), Plus(If(Var("y"), Var("z")), Var("a")))



SDF Priorities - Solution

An If not surrounded by parentheses can only occur at the right-hand side of a Plus

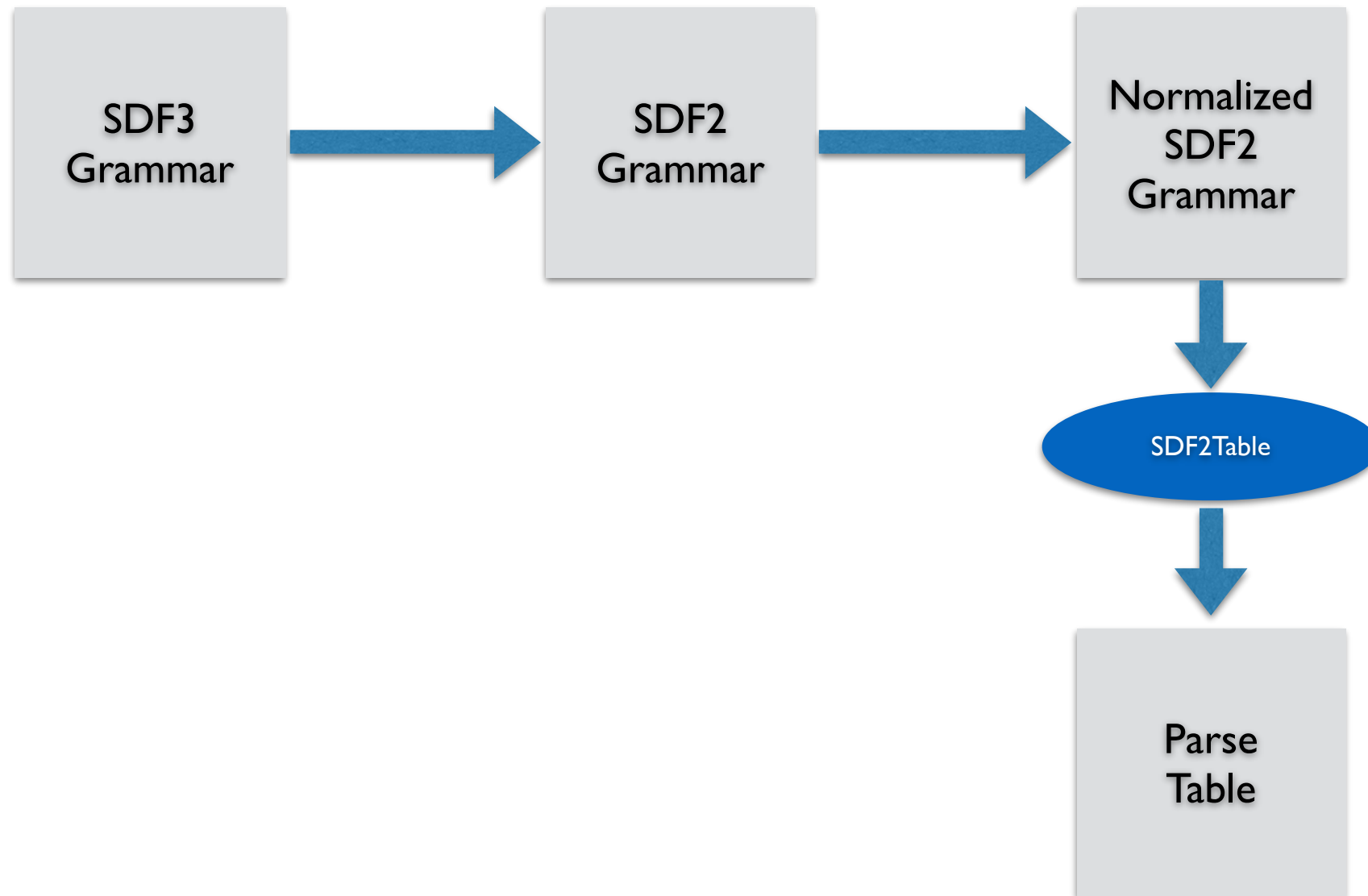
context-free syntax

Exp	=	R
L	=	"(" Exp ")" {bracket}
R	=	"(" Exp ")" {bracket}
L.VarL	=	ID
R.VarR	=	ID
R.PlusR	=	L "+" R {left}
L.PlusL	=	L "+" L {left}
R.If	=	"if" Exp "then" R

x + if y then z + a

PlusR(VarL("x"), If(VarR("y"), PlusR(VarL("z"), VarR("a"))))

SDF3 Normalisation



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