SPSC: a Simple Supercompiler in Scala

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PU'09

To program is to understand

A program should reflect
an understanding of
the problem domain

We would like...

- To demystify supercompilation for a programmer
- In order to do this we want:
  - To present the core of supercompilation in the form of a program
  - The code of the supercompiler should be small and clear
  - A minimalistic input language

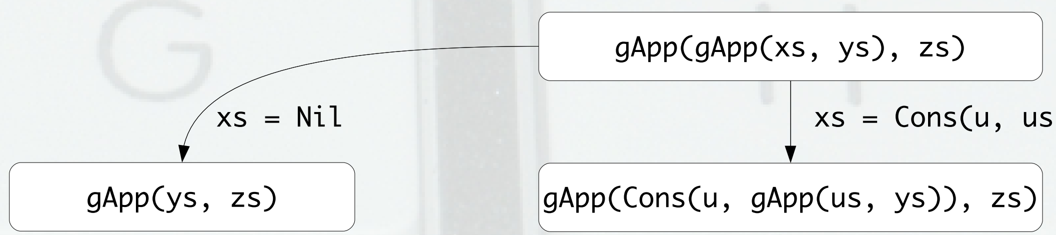
Supercompilation in a Nutshell

```
gApp(Nil(), vs) = vs;
gApp(Cons(u, us), vs) = Cons(u, gApp(us, vs));
```

```
gApp(gApp(xs, ys), zs)
```

Supercompilation in a Nutshell

```
gApp(Nil(), vs) = vs;
gApp(Cons(u, us), vs) = Cons(u, gApp(us, vs));
```



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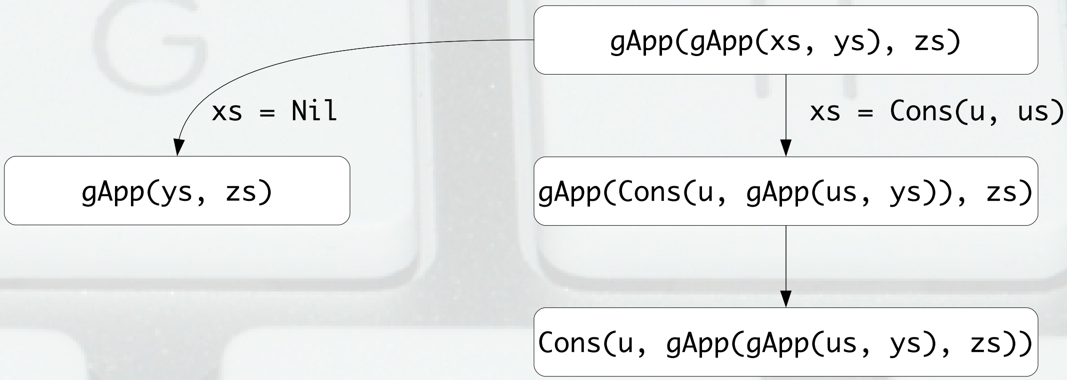

Supercompilation in a Nutshell

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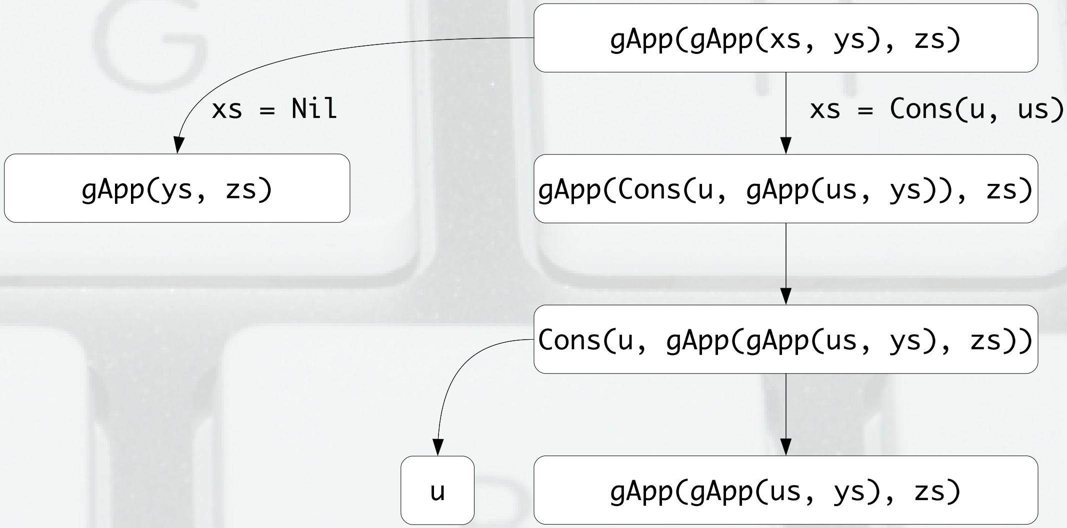

Supercompilation in a Nutshell

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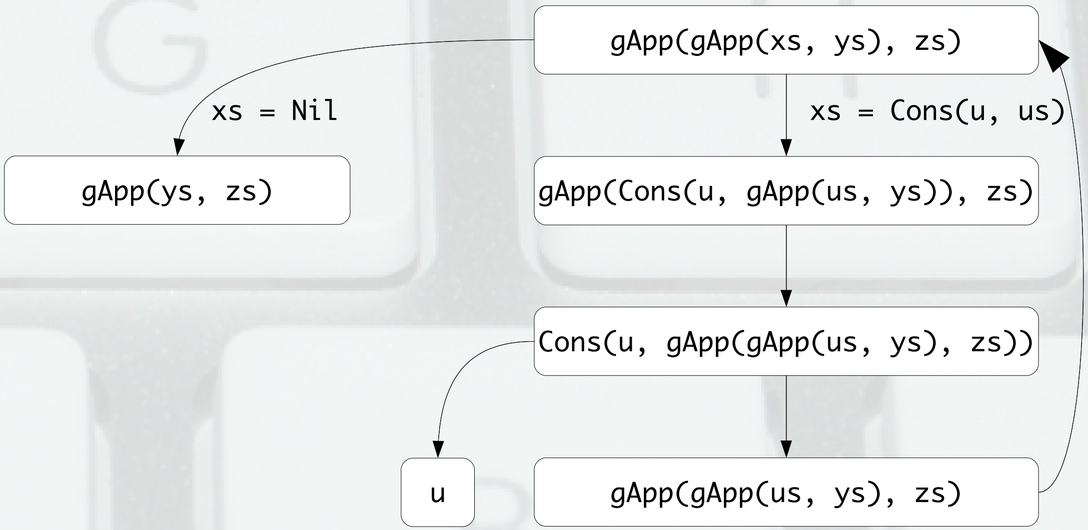

Supercompilation in a Nutshell

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gApp(Nil(), vs) = vs;
gApp(Cons(u, us), vs) = Cons(u, gApp(us, vs));
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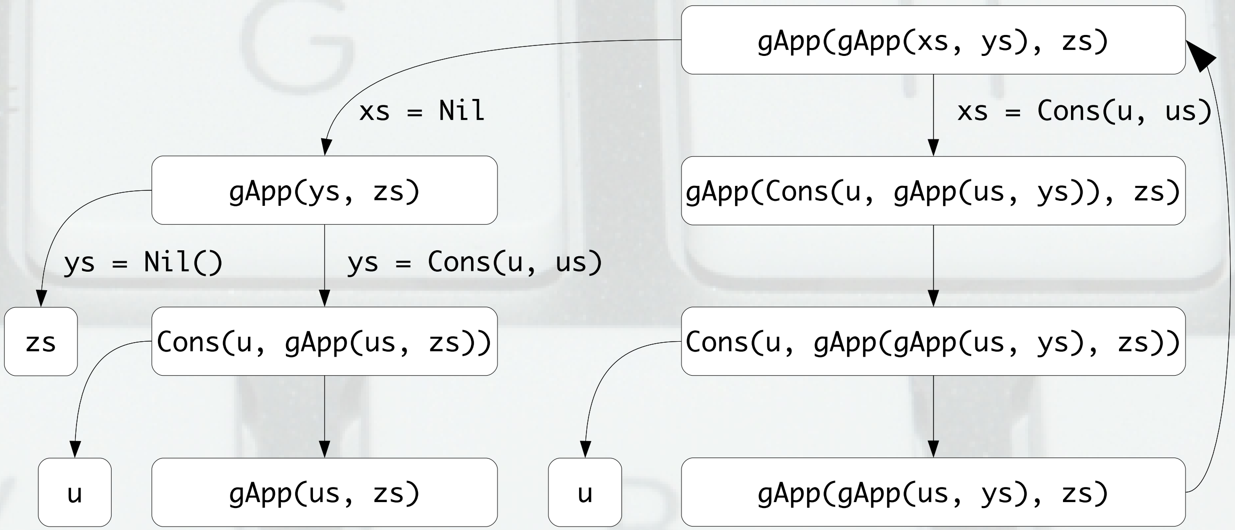
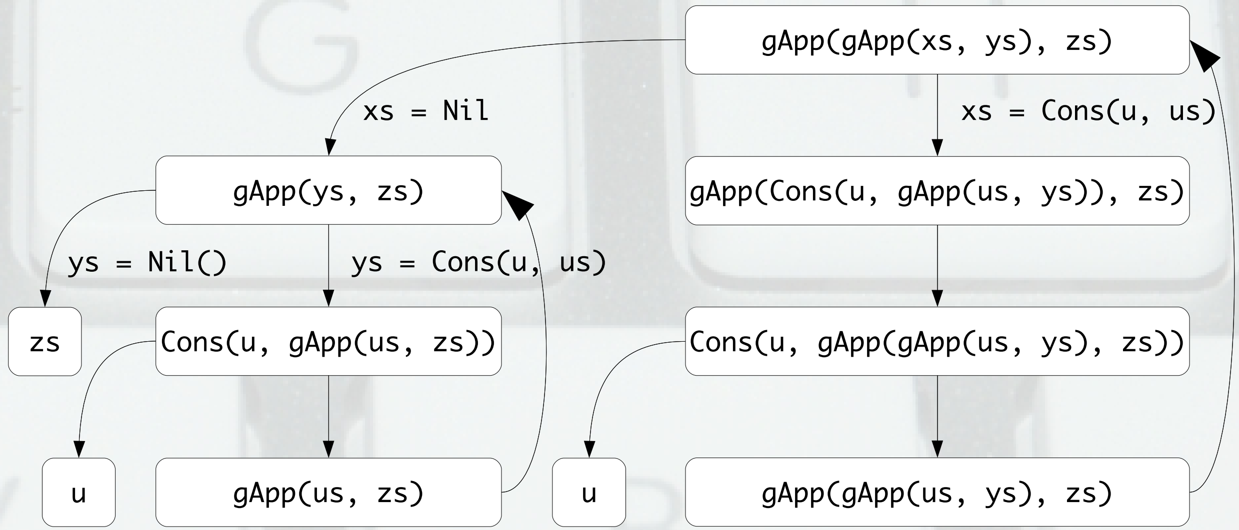


Supercompilation in a Nutshell

```
gApp(Nil(), vs)         = vs;
gApp(Cons(u, us), vs) = Cons(u, gApp(us, vs));
```



Supercompilation in a Nutshell

```
gApp(Nil(), vs)         = vs;
gApp(Cons(u, us), vs) = Cons(u, gApp(us, vs));
```

```
gApp(gApp(xs, ys), zs)
```

```
gApp1(xs, ys, zs)
```

```
gApp1(Nil(), y, z)          = gApp2(y, z);
gApp1(Cons(v1, v2), y, z) = Cons(v1, gApp1(v2, y, z));

gApp2(Nil(), z)             = z;
gApp2(Cons(v3, v4), z)     = Cons(v3, gApp2(v4, z));
```

Quest for practical supercompilers

1974	V. Turchin presented supercompilation to a group of students at seminars in Moscow
1980s	V. Turchin developed first supercompilers for the functional programming language Refal (CUNY, New York)
1980s – – 1990s	Papers by V. Turchin on supercompilation of Refal
1993 – – 2000s	Andrei Nemytykh (IPS RAS, Pereslavl-Zalessky) continued work on Turchin’s supercompiler and completed it
1998 – – 2000s	Java Supercompiler by Andrei Klimov, Arkady Klimov and Artem Shvorin (Keldysh Institute of Applied Mathematics, RAS, Moscow)

[AK]

Quest for understandable supercompilers

1986 V. Turchin "The Concept of a Supercompiler". ACM TOPLAS 8(3): 292-325

1988 V. Turchin "The Algorithm of Generalization in the Supercompiler". Partial Evaluation and Mixed Computation, North-Holland, 341-353

. . .

1993 The first understandable supercompiler and paper by R. Glück and A. Klimov "Occam's razor in metacomputation: the notion of a perfect process tree". LNCS 724: 112-123

1993 Book by S. Abramov "Metacomputation and its application" (in Rus)

1996 M.H. Sørensen, R. Glück, N.D. Jones "A Positive Supercompiler". J. Funct. Program. 6(6): 811-838

. . .

2009 I. Klyuchnikov, S. Romanenko "SPSC: a Simple Supercompiler in Scala". PU'09

[AK]

Input Language

```
p ::= d1 ... dn program
d ::= f (x1, ... , xn) = e;                    f-function
    | g (q1, x1, ... , xn) = e1;               g-function
      ...
      g (qm, x1, ... , xn) = em;

e ::= x variable
    | c ( e1, ... , en)                        constructor
    | f ( e1, ... , en)                        call to f-function
    | g ( e1, ... , en)                        call to g-function

q ::= c v1 ... vn                              pattern
```

Implementation language??

- Easy to understand
- Easy to use (IDE, debugger, libs, …)
- Functional
- Also cool

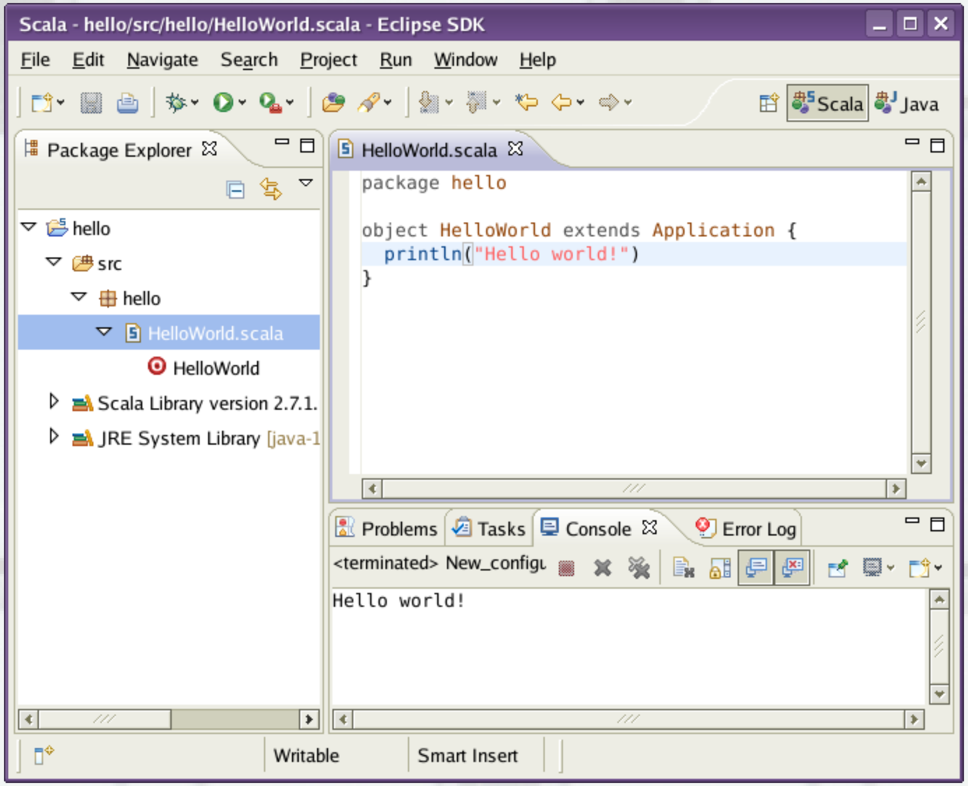
Scala makes a buzz

Scala

Scalable **La**nguage

- FP support
- OOP support
- Compiles to JVM bytecode
- Ready for production – Twitter is rewritten into Scala

Scala makes a buzz



- IDE Support
- Convenient debugger
- Great community
- Strong theoretical base

Scala by Example

pragmatic OOP

```
abstract class Def {def name: String}

    class FFun(name: String, args: List[Var], term: Term) extends Def {
  override def toString =
    name + args.mkString("(", ", " ,")") + " = " + term + ";"
}

    class GFun(name: String, p: Pat, args: List[Var], term: Term) extends Def {
  override def toString =
    name + (p :: args).mkString("(", ", " ,")")  + " = " + term + ";"
}
```

Scala by Example

pattern matching with case classes

```
abstract class Def {def name: String}

case class FFun(name: String, args: List[Var], term: Term) extends Def {
  override def toString =
     name + args.mkString("(", ", " ,")") + " = " + term + ";"
}

case class GFun(name: String, p: Pat, args: List[Var], term: Term) extends Def {
  override def toString =
     name + (p :: args).mkString("(", ", " ,")")  + " = " + term + ";"
}

case class Program(defs: List[Def]){
  val f = (defs :\ (Map[String, FFun]()))
    {case (x: FFun, m) => m + (x.name -> x); case (_, m) => m}
  val g = (defs :\ (Map[(String, String), GFun]()))
    {case (x: GFun, m) => m + ((x.name, x.p.name) -> x); case (_, m) => m}
  val gs = (defs :\ Map[String, List[GFun]]().withDefaultValue(Nil))
    {case (x: GFun, m) => m + (x.name -> (x :: m(x.name))); case (_, m) => m}
  override def toString = defs.mkString("\n")
}
```

Scala by Example

functional objects

```
abstract class Def {def name: String}

case class FFun(name: String, args: List[Var], term: Term) extends Def {
  override def toString =
     name + args.mkString("(", ", " ,")") + " = " + term + ";"
}

case class GFun(name: String, p: Pat, args: List[Var], term: Term) extends Def {
  override def toString =
     name + (p :: args).mkString("(", ", " ,")")  + " = " + term + ";"
}
```

```
val g = p.g(name, cname)
```

```
case class Program(defs: List[Def]){
  val f = (defs :\ (Map[String, FFun]()))
    {case (x: FFun, m) => m + (x.name -> x); case (_, m) => m}
  val g = (defs :\ (Map[(String, String), GFun]()))
    {case (x: GFun, m) => m + ((x.name, x.p.name) -> x); case (_, m) => m}
  val gs = (defs :\ Map[String, List[GFun]]().withDefaultValue(Nil))
    {case (x: GFun, m) => m + (x.name -> (x :: m(x.name))); case (_, m) => m}
  override def toString = defs.mkString("\n")
}
```

Scala by Example

higher-order functions, almost any names for defs...

```
abstract class Def {def name: String}

case class FFun(name: String, args: List[Var], term: Term) extends Def {
  override def toString =
     name + args.mkString("(", ", " ,")") + " = " + term + ";"
}

case class GFun(name: String, p: Pat, args: List[Var], term: Term) extends Def {
  override def toString =
     name + (p :: args).mkString("(", ", " ,")")  + " = " + term + ";"
}

case class Program(defs: List[Def]){
  val f = (defs :\ (Map[String, FFun]()))
    {case (x: FFun, m) => m + (x.name -> x); case (_, m) => m}
  val g = (defs :\ (Map[(String, String), GFun]()))
    {case (x: GFun, m) => m + ((x.name, x.p.name) -> x); case (_, m) => m}
  val gs = (defs :\ Map[String, List[GFun]]().withDefaultValue(Nil))
    {case (x: GFun, m) => m + (x.name -> (x :: m(x.name))); case (_, m) => m}
  override def toString = defs.mkString("\n")
}
```

Scala by Example

to mutate (and how) or not to mutate?

```
def findSubst(t1: Term, t2: Term) = {
  val map = scala.collection.mutable.Map[Var, Term]()
  def walk(t1: Term, t2: Term): Boolean = (t1, t2) match {
    case (v1: Var, _) => map.put(v1, t2) match {
      case None => true;
      case Some(t3) => t2 == t3
    }
    case (e1: CFG, e2:CFG) if shellEq(e1, e2) =>
      List.forall2(e1.args, e2.args)(walk)
    case _ => false
  }
  if (walk(t1, t2)) map.readOnly else null
}
```

Scala by Example

to mutate (and how) or not to mutate?

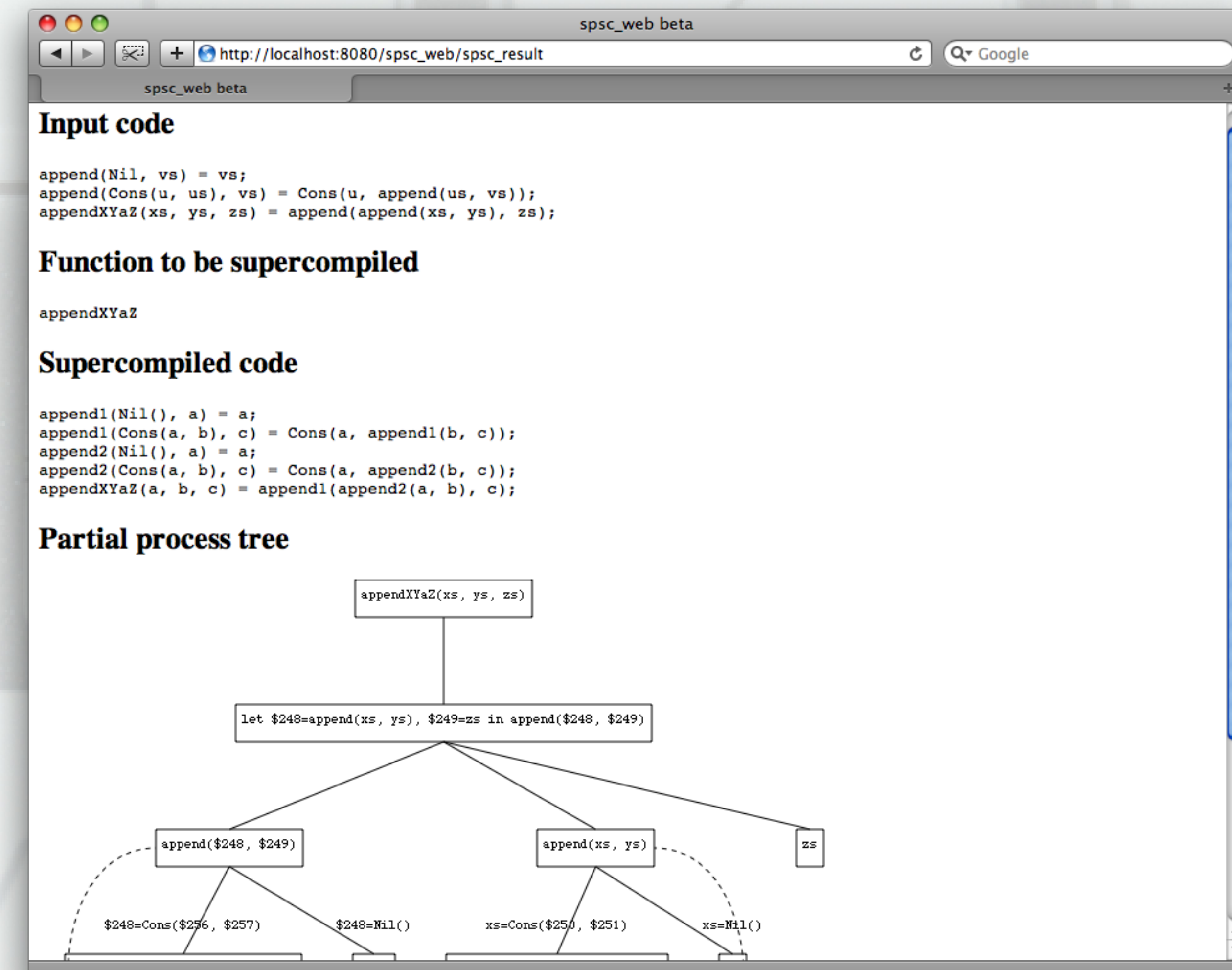
```
def findSubst(t1: Term, t2: Term) = {
  var map = Map[Var, Term]()
  def walk(t1: Term, t2: Term): Boolean = (t1, t2) match {
    case (v1: Var, _) => map.get(v1) match {
      case None => map += (v1 -> t2); true
      case Some(t3) => t2 == t3
    }
    case (e1: CFG, e2:CFG) if shellEq(e1, e2) =>
      List.forall2(e1.args, e2.args)(walk)
    case _ => false
  }
  if (walk(t1, t2)) map else null
}
```

Scala by Example

real DSL

```scala
object SParsers extends StandardTokenParsers with ImplicitConversions {
  ...
  def prog = definition+
  def definition: Parser[Def] = gFun | fFun
  def term: Parser[Term] = fcall | gcall | ctr | vrb
  def vrb = lid ^^ Var
  def pat = uid ~ ("(" ~> repsep(vrb, ",") <~ ")") ^^ Pat
  def fFun =
    fid ~ ("(" ~> repsep(vrb, ",") <~ ")") ~ ("=" ~> term <~ ";") ^^ FFun
  def gFun =
   gid ~ ("("~>pat) ~ (((","~>vrb)*) <~ ")") ~ ("=" ~> term <~ ";") ^^ GFun
  def ctr = uid ~ ("(" ~> repsep(term, ",") <~ ")") ^^ Ctr
  def fcall = fid ~ ("(" ~> repsep(term, ",") <~ ")") ^^ FCall
  def gcall = gid ~ ("(" ~> repsep(term, ",") <~ ")") ^^ GCall
}
```

Time to try it



Input code

```
append(Nil, vs) = vs;
append(Cons(u, us), vs) = Cons(u, append(us, vs));
appendXYaZ(xs, ys, zs) = append(append(xs, ys), zs);
```

Function to be supercompiled

```
appendXYaZ
```

Supercompiled code

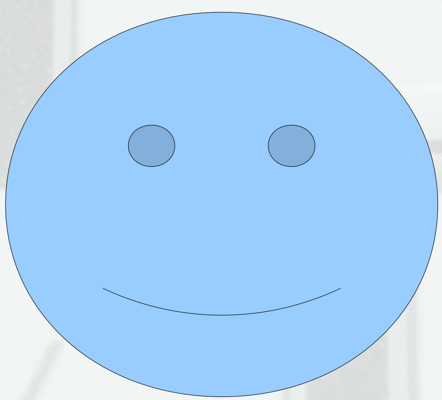
```
append1(Nil(), a) = a;
append1(Cons(a, b), c) = Cons(a, append1(b, c));
append2(Nil(), a) = a;
append2(Cons(a, b), c) = Cons(a, append2(b, c));
appendXYaZ(a, b, c) = append1(append2(a, b), c);
```

Partial process tree

Thanks!

Writing it is easy,
understanding it is hard.

Anonymous



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