Yin-Yang: Transparent Deep Embedding of DSLs

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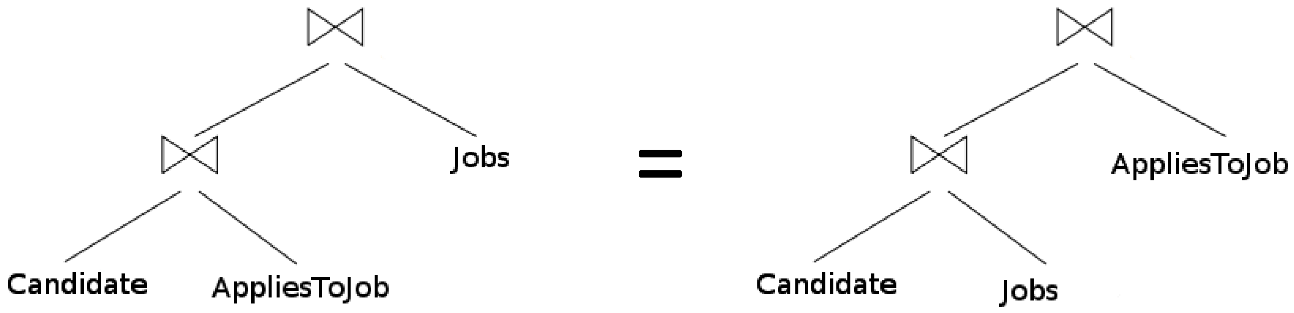
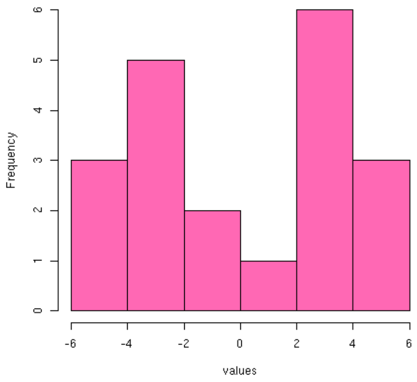
PERVASIVE
PARALLELISM
LABORATORY
PPL

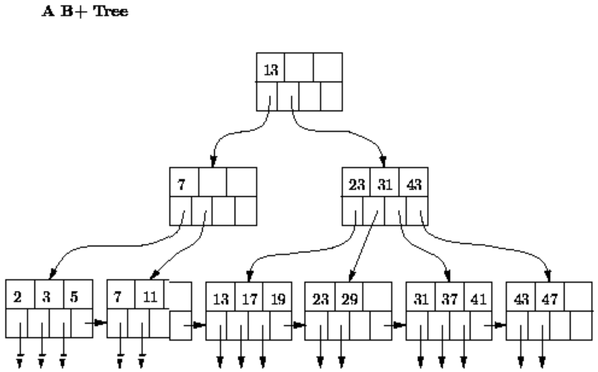
Good Performance: SQL

1. Compiler has domain knowledge

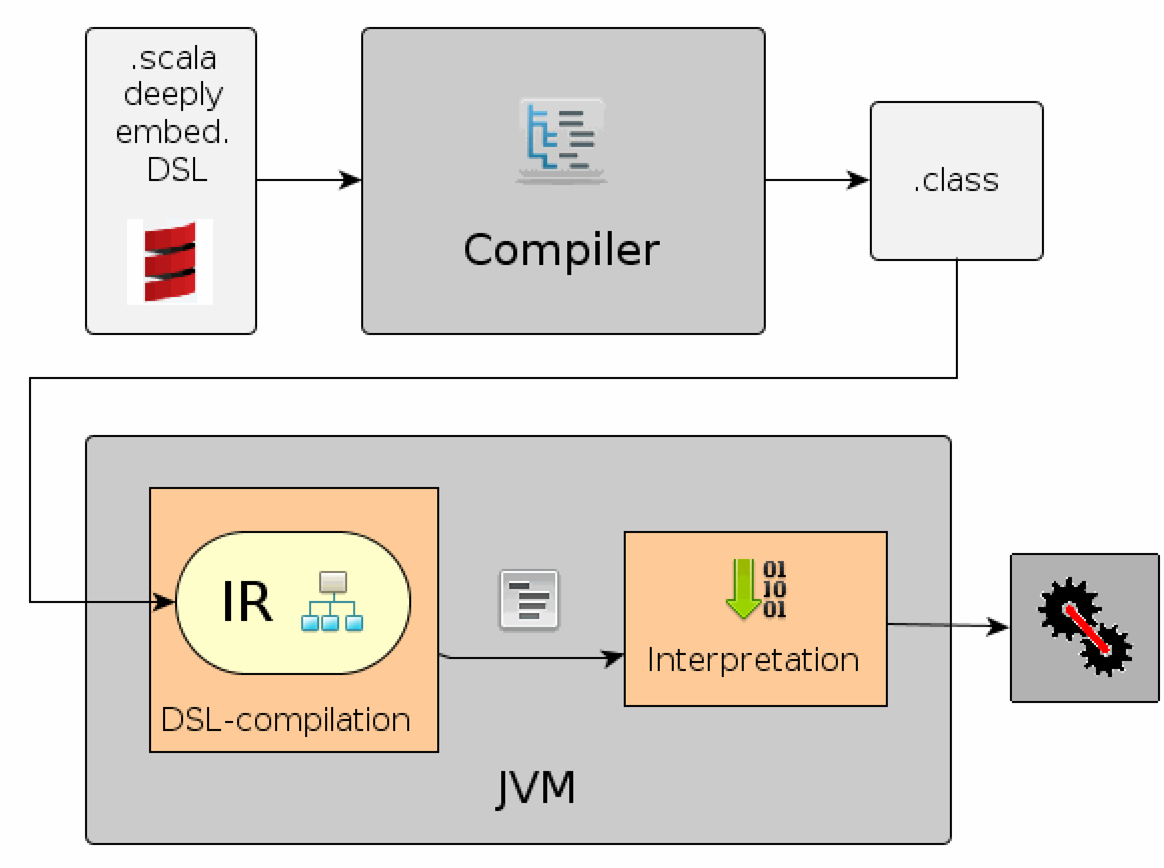


2. Compiled at run-time (access to data)





Deep Embedding



Deep Embedding - LMS

```
trait Base { trait Exp[T]
  type Rep[T] = Exp[T]
  case class Const[T](t: T) extends Exp[T]
  implicit def unit[T](t: T): Rep[T] = Const(t)
}

trait RegexDSL extends Base {
  case class Matches(
    t: Rep[String],
    p: Rep[String]) extends Exp[Boolean]
  object regex {
    def matches(t: Rep[String], p: Rep[String) =
      Matches(t, p)
  }
  def main() =
    regex.matches("42", "Answer to the Ultimate…")
}
```

Program Text is Not All

```
regex.matches("42", "Answer to the Ultimate…")
```

Convoluted Interface

```
def infix_-(lhs: Rep[Float], rh: Rep[Int])
  (implicit o: Overloaded,
   ctx: SourceContext): Rep[Float]
```

```
def infix_-(lhs: Rep[Int], rh: Rep[Int])
  (implicit o: Overloaded,
   ctx: SourceContext): Rep[Int]
```

Type Errors

```
val one: Rep[Int] = 1
val void: Rep[Unit] = ()
one + void
```

No implicit view available from RepDSL.this.Rep[Unit] => Int.

Deep DSL Embedding

X Nice interface

X Comprehensible type errors

X Easy debugging

X Consistent Documentation

X Consistent with the host language

✓ Domain-specific analysis

✓ Fast

Shallow Embedding

```
package object regex {
  def regexDSL[T](b: => T) = b
  def matches(text: String, pat: String): Boolean =
    text.matches(pat)
}
```

Shallow Embedding

✓ Nice interface

✓ Comprehensible type errors

✓ Easy debugging

✓ Consistent documentation

✓ Consistent with the host language

X Domain-specific analysis

X Fast

During program development we do not care about performance!

✓ Use shallow embedding for development

✓ Use deep embedding in production

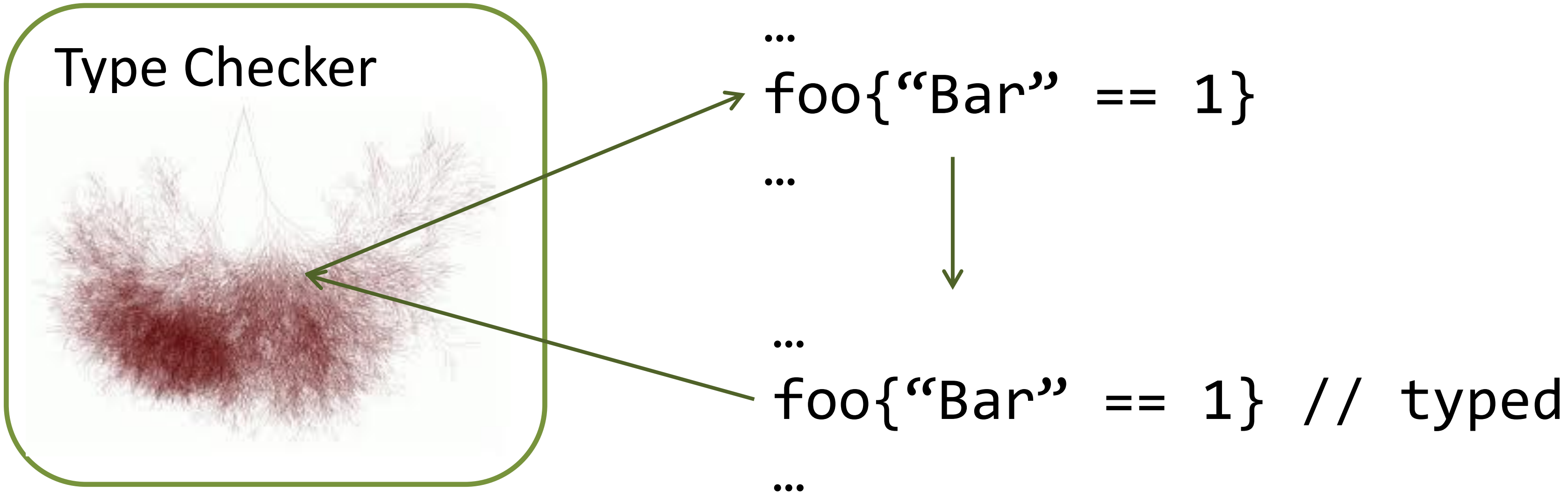
Macros

Compile-time meta-programming

Completely transparent to the users

```
def fix_==[T](block: => T): T =
  macro fix_==Impl
```

Regular Workflow

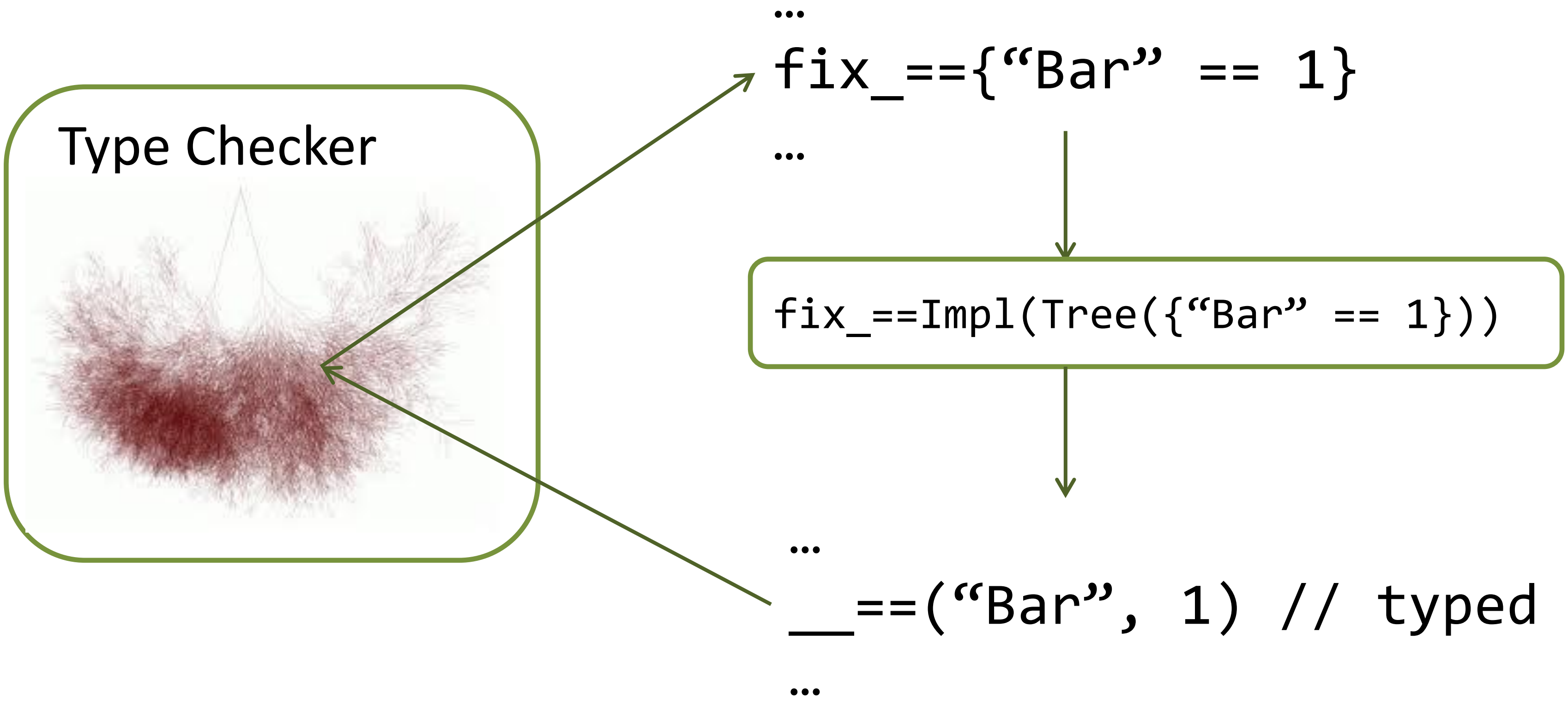


Type Checker

```
…
foo{“Bar” == 1}
…
```

```
…
foo{“Bar” == 1} // typed
…
```

Macro Workflow



Type Checker

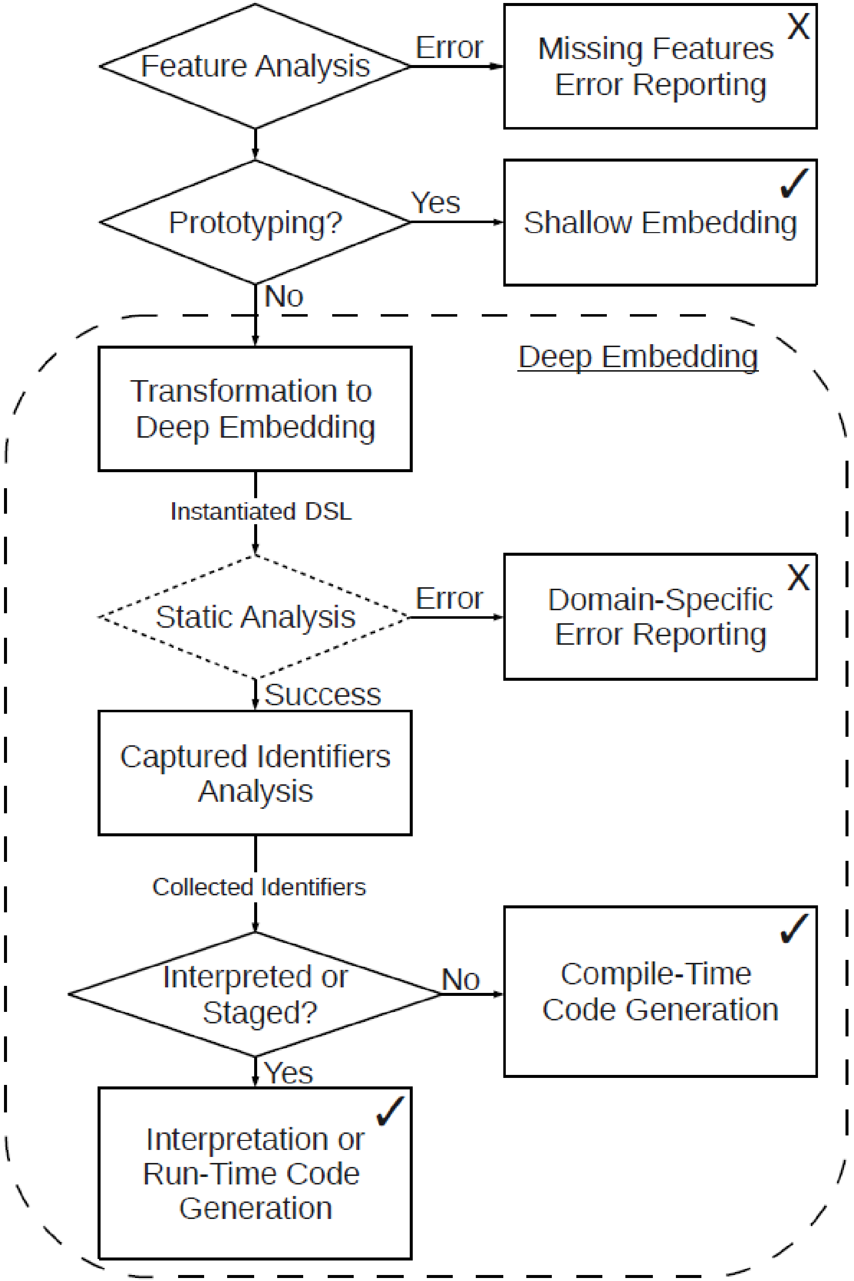
```
…
fix_=={“Bar” == 1}
…
```

```
fix_==Impl(Tree({“Bar” == 1}))
```

```
…
__==(“Bar”, 1) // typed
…
```

Yin-Yang Library

Uses macros to reliably translate shallow programs to deep programs!



Feature Analysis

Error

Missing Features Error Reporting

X

Prototyping?

Yes

Shallow Embedding

✓

No

Deep Embedding

Transformation to Deep Embedding

Instantiated DSL

Static Analysis

Error

Domain-Specific Error Reporting

X

Success

Captured Identifiers Analysis

Collected Identifiers

Interpreted or Staged?

No

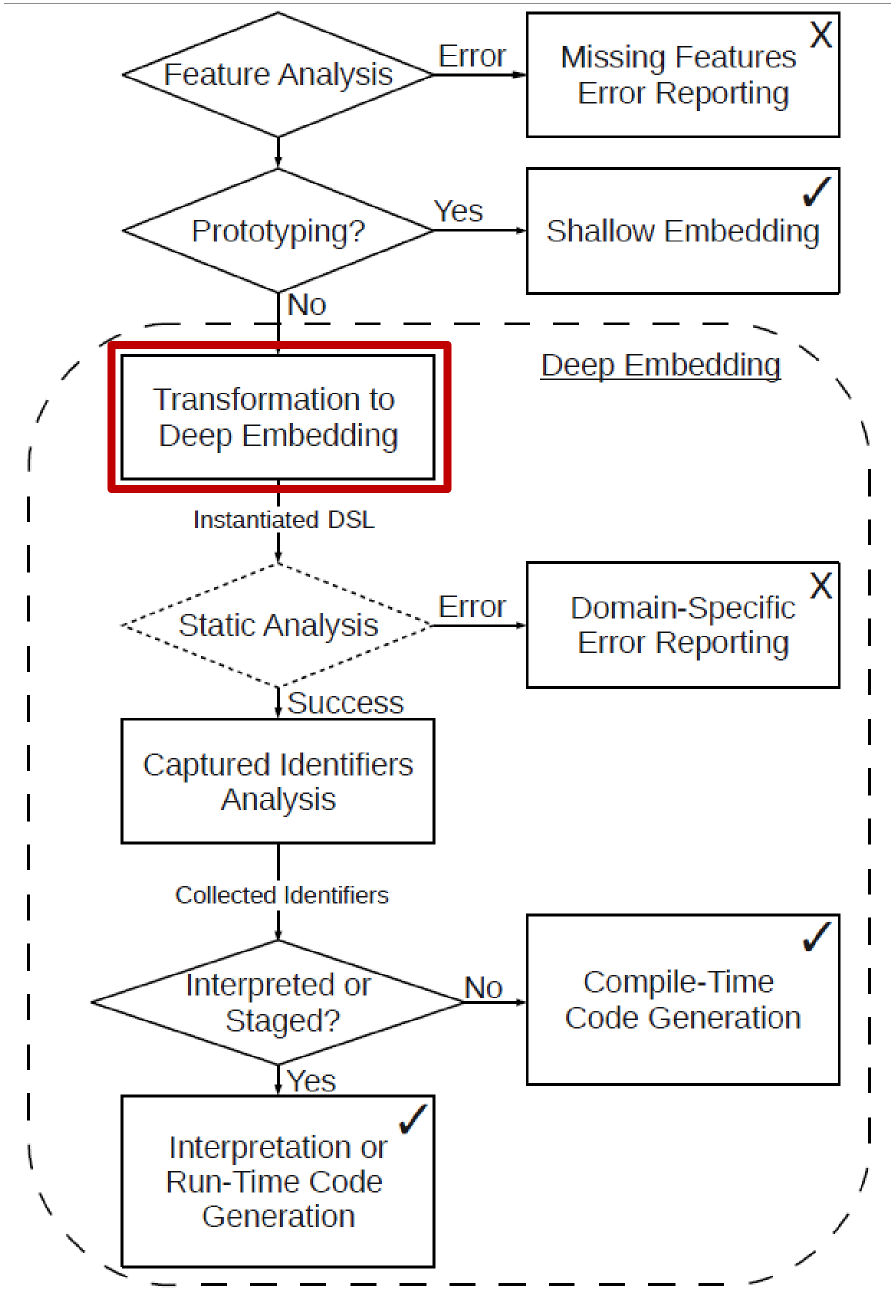
Compile-Time Code Generation

✓

Yes

Interpretation or Run-Time Code Generation

✓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Shallow Program

```
val readHGTG = ...; val text = "42";
val pattern = "Answer to the Ultimate Q..."
regexDSL {
  val res = if (readHGTG)
    matches(
       text,
       pattern
    )
    else true
  res
}
```

Ascription Transformation

```
val readHGTG = ...; val text = "42";
val pattern = "Answer to the Ultimate Q..."
regexDSL {
  val res: Boolean = ((if (readHGTG)
    (regex.`package`.matches(
       text,
       pattern
    ): Boolean)
    else true): Boolean)
  res
}
```

Lift Literals Transformation

```
val readHGTG = ...; val text = "42";
val pattern = "Answer to the Ultimate Q..."
regexDSL {
  val res: Boolean = ((if (readHGTG)
    (regex.`package`.matches(
       text,
       pattern
    ): Boolean)
  else lift(true)): Boolean)
  res
}
```

Virtualization Transformation

```
val readHGTG = ...; val text = "42";
val pattern = "Answer to the Ultimate Q..."
regexDSL {
  val res: Boolean = ((__ifThenElse(readHGTG,
    (regex.`package`.matches(
       text,
       pattern
    ): Boolean),
    lift(true)): Boolean)
  res
}
```

Scope Injection Transformation

```
val readHGTG = ...; val text = "42";
val pattern = "Answer to the Ultimate Q..."
regexDSL {
  val res: Boolean = ((__ifThenElse(readHGTG,
    (this.regex.`package`.matches(
       text,
       pattern
    ): Boolean),
    lift(true)): Boolean)
  res
}
```

Type Transformation

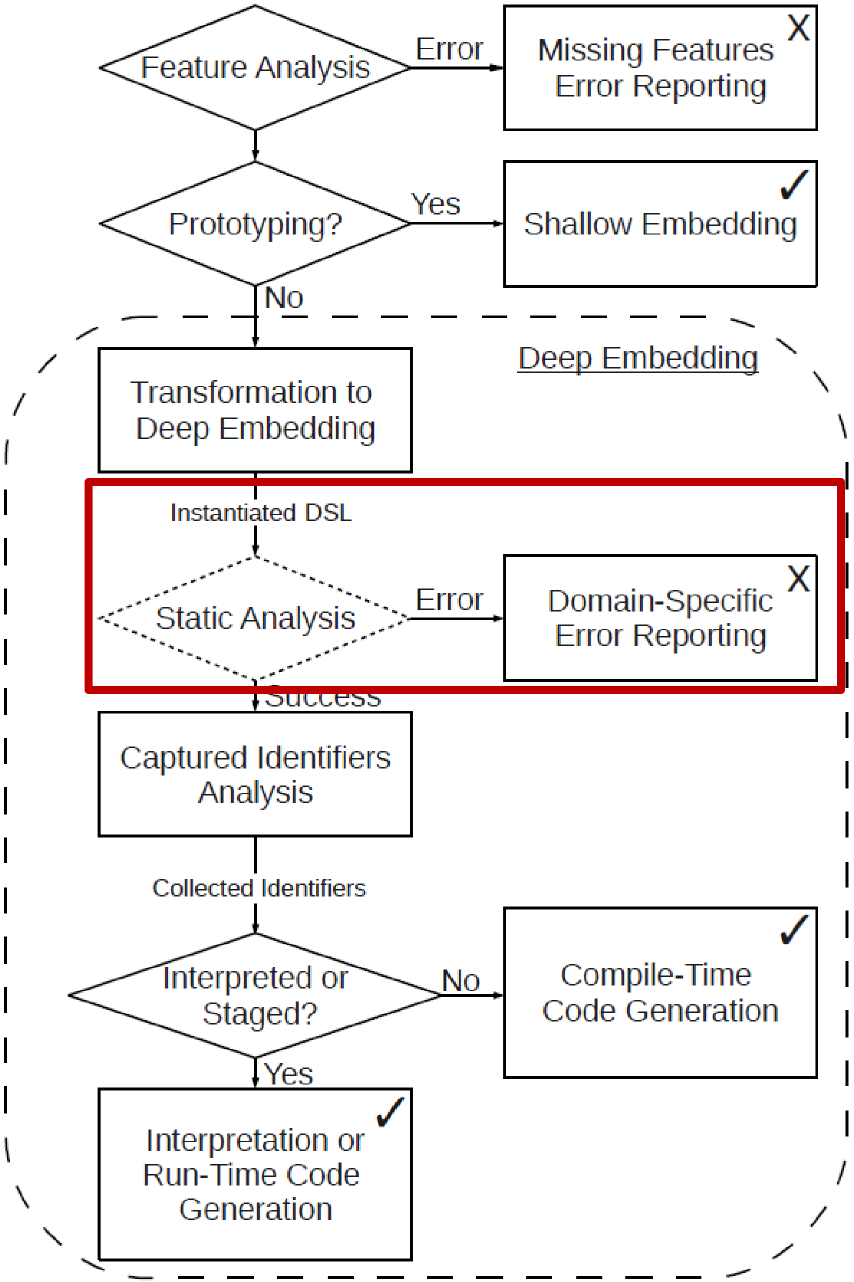
```
val readHGTG = ...; val text = "42";
val pattern = "Answer to the Ultimate Q..."
regexDSL {
  val res: this.Rep[Boolean] =
  ((__ifThenElse(readHGTG,
    (this.regex.`package`.matches(
       text,
       pattern
    ): this.Rep[Boolean]),
    lift(true)): this.Rep[Boolean])
  res
}
```

Hole Transformation

```
val readHGTG = ...; val text = "42";
val pattern = "Answer to the Ultimate Q..."
regexDSL {
  val res: this.Rep[Boolean] =
  ((__ifThenElse(hole(typeTag[Boolean],1)
    (this.regex.`package`.matches(
       hole(typeTag[String], 2),
       hole(typeTag[String], 3)
    ): this.Rep[Boolean]),
    lift(true)): this.Rep[Boolean])
res
}
```

Cake Insertion

```
val readHGTG = ...; val text = "42";
val pattern = "Answer to the Ultimate Q..."
new RegexDSL { def main() {
  val res: this.Rep[Boolean] =
  ((__ifThenElse(hole(typeTag[Boolean],1)
    (this.regex.`package`.matches(
       hole(typeTag[String], 2),
       hole(typeTag[String], 3)
    ): this.Rep[Boolean]),
    lift(true)): this.Rep[Boolean])
res
}}
```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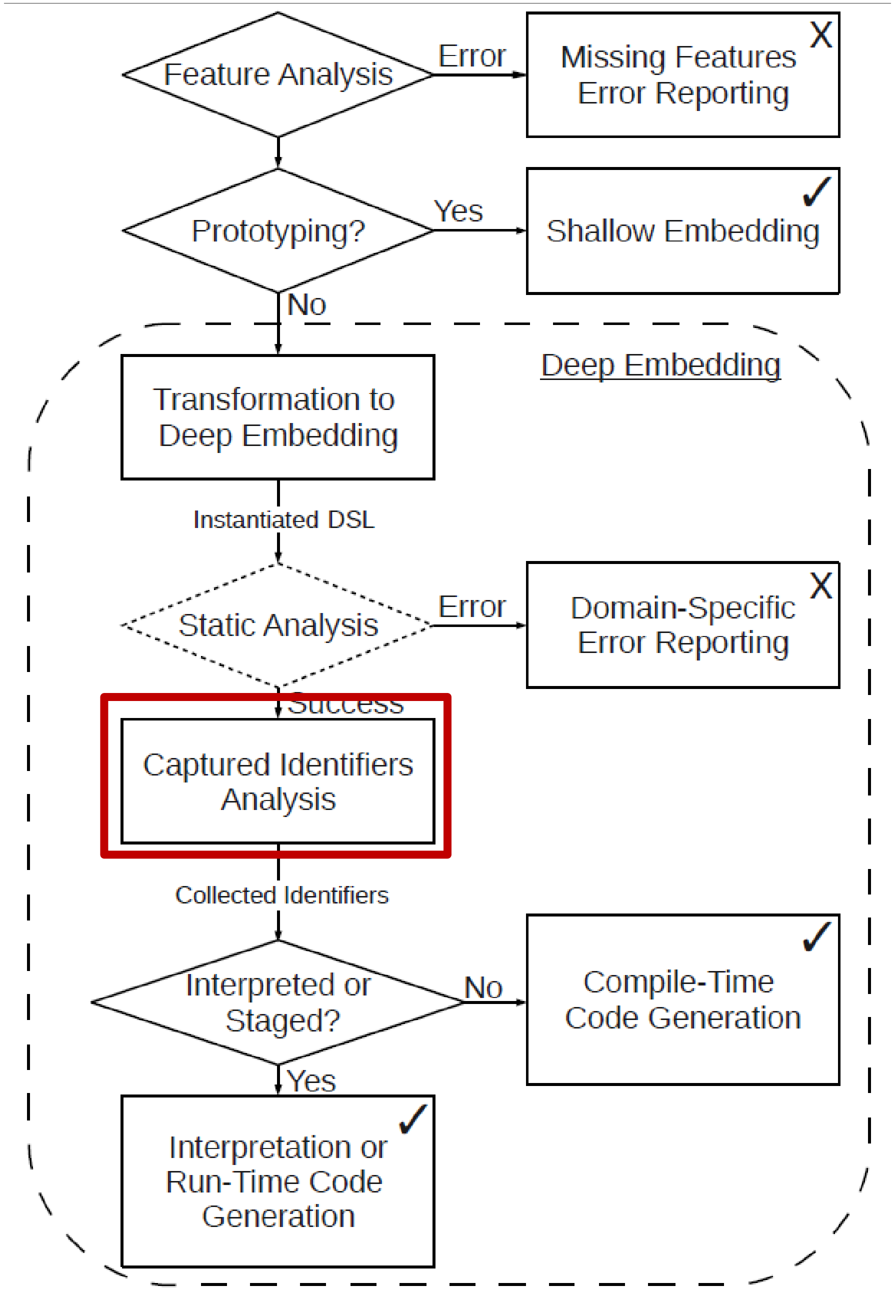
Reflective Instantiation

```
val dsl =
  c.eval(new RegexDSL {def main()={…}}
```

Domain-Specific Analysis

```
dsl.staticallyAnalyze(c)
```

Reports errors at compile time!



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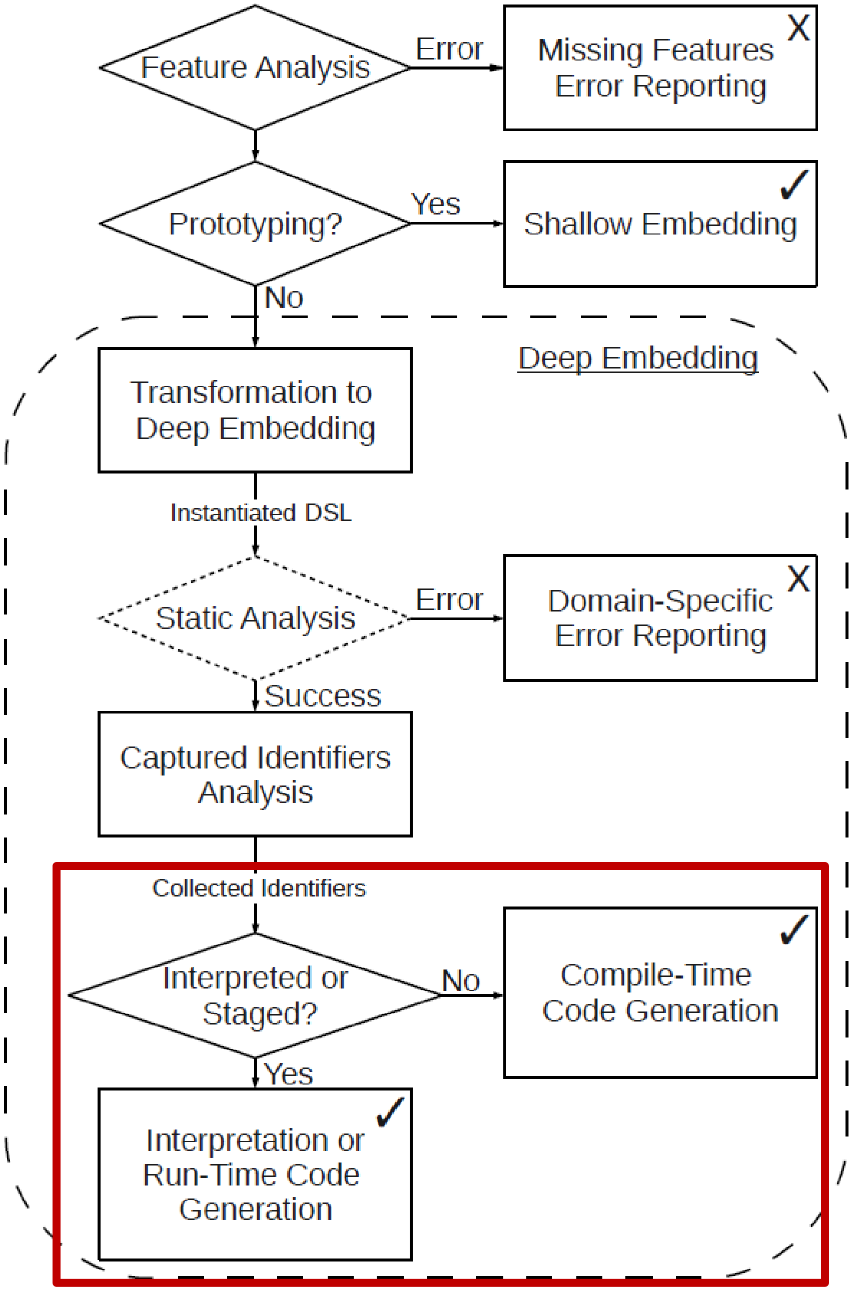
Captured Identifiers Analysis

```
val requiredIdents =
  dsl.stagingAnalysis()
```

if (*requiredIdents* != *Nil*)

```
val readHGTG = ...; val text = "42";
val pattern = "Answer to the Ultimate Q..."
new RegexDSL { def main() {
  val res: this.Rep[Boolean] =
  ((__ifThenElse(hole(typeTag[Boolean],1)
    (this.regex.`package`.matches(
       hole(typeTag[String], 2),
       lift(pattern)
    ): this.Rep[Boolean]),
    lift(true)): this.Rep[Boolean])
res
}}
```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Compile vs. Runtime

```
if (requiredIdents == Nil)
  // compile at compile time
  c.parse(dsl.gnerateCode())
else
  // compile at run time
  c.expr(Block(
    guards,
    dslCake,
    dslInvocation
  )
```

Deep DLSs: Idents vs. Constants

- Deep embedding does not distinguish constants and identifiers

- To check for recompilation it needs to lift the whole program on each execution

Guards with Deep DSLS

```
val s = text.map(incChar)
  if (matches(s, pattern))
    println("OK")
```

How long does the lifting take?

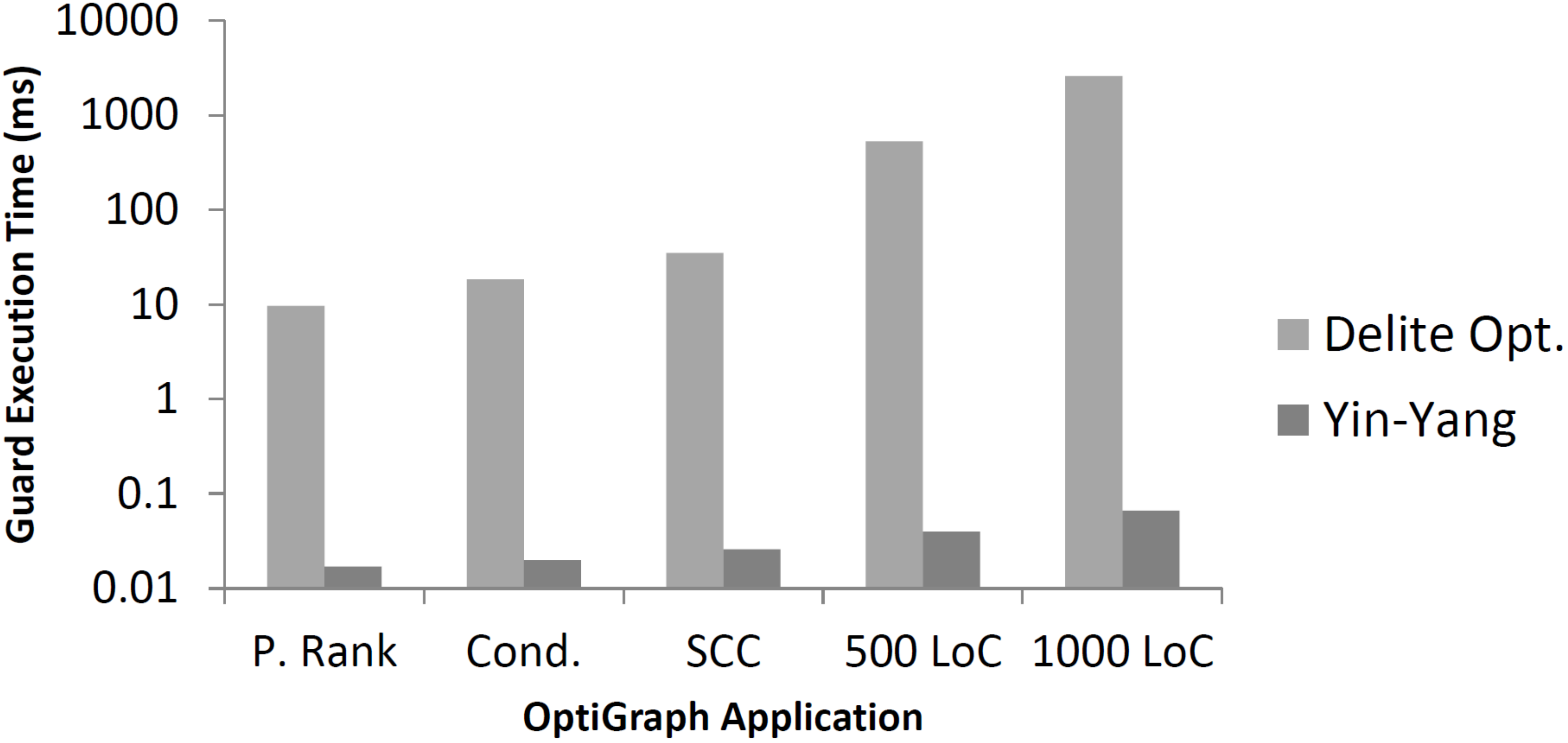
Shallow program processes 100 KB string
for the time of one lifting!

Guarded Recompilation

```
if (pattern != Cache.prevValue(<uid>))
  Cache.setProgram(<uid>)(
   new RegexDSL{def main()={…}}
  )


Cache.program(<uid>)(cond, text)
```

Evaluation


10000
1000
100
10
1
0.1
0.01
Guard Execution Time (ms)
P. Rank
Cond.
SCC
500 LoC
1000 LoC
OptiGraph Application
Delite Opt.
Yin-Yang

Contributions

- Completely transparent deep embedding
- Completely compiler agnostic
- Compilation at either compile or run time
- Efficient guarded recompilation

Slick DSL with Macors

- Macro version took months to develop

- Duplicate of the deep embedding

- Does not work for all cases

Macro Version of Slick

- Requires same things as Yin-Yang
  - Hole Transformation
  - Virtualization
  - Compile-time evaluation

- These transformation are non-trivial

Slick with Yin-Yang

- Three weeks development

- Wires to the existing DSL (no duplication)

- More features that the macro version

Future Work

- Class virtualization

- Cross compilation unit operation

- Yin-Yang as a modular library for DSLs

References

- Yin-Yang
  - http://github.com/vjovanov/mpde
  - http://infoscience.epfl.ch/record/185832/files/yinyang.pdf?version=2

- Learn LMS
  - http://scala-lms.github.com
  - http://github.com/stanford-ppl/Delite

Questions?

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