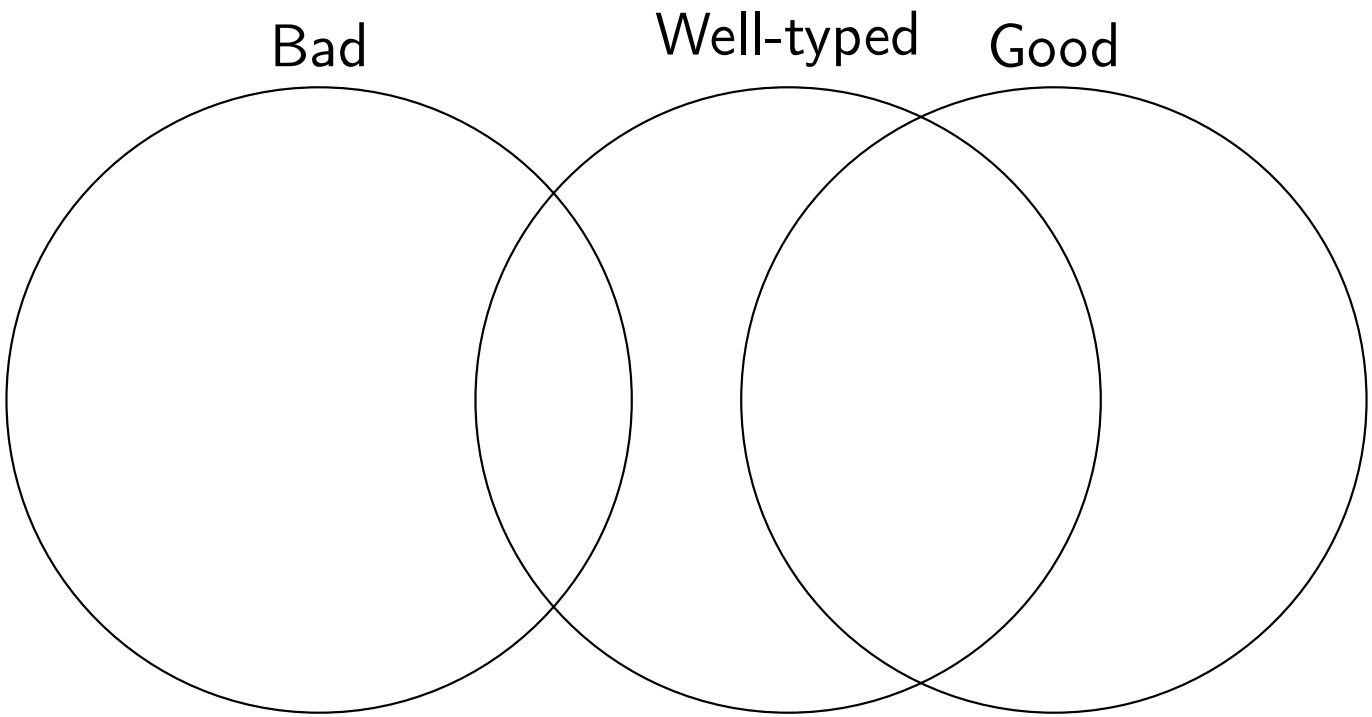
Dependently Typed Programming in Idris
A Demo

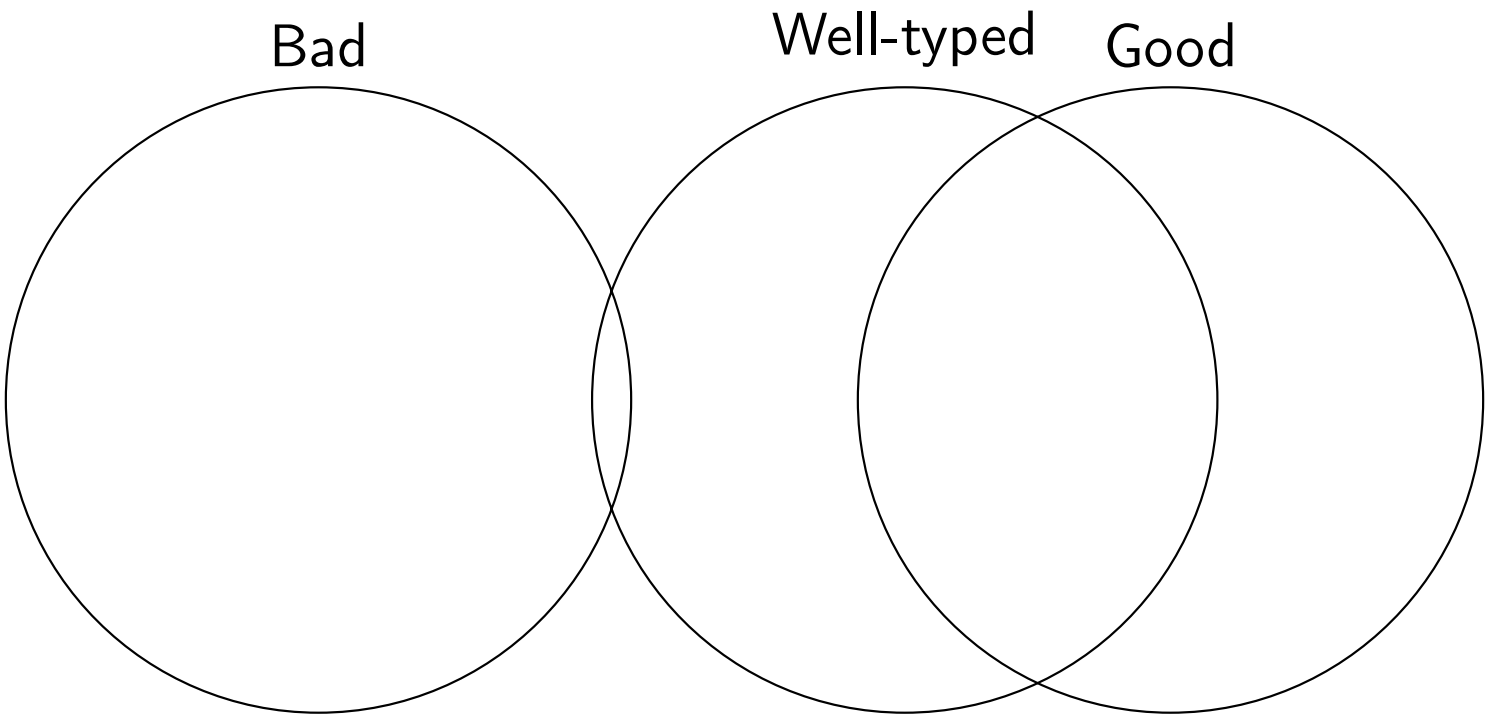
David Raymond Christiansen

March 26, 2014

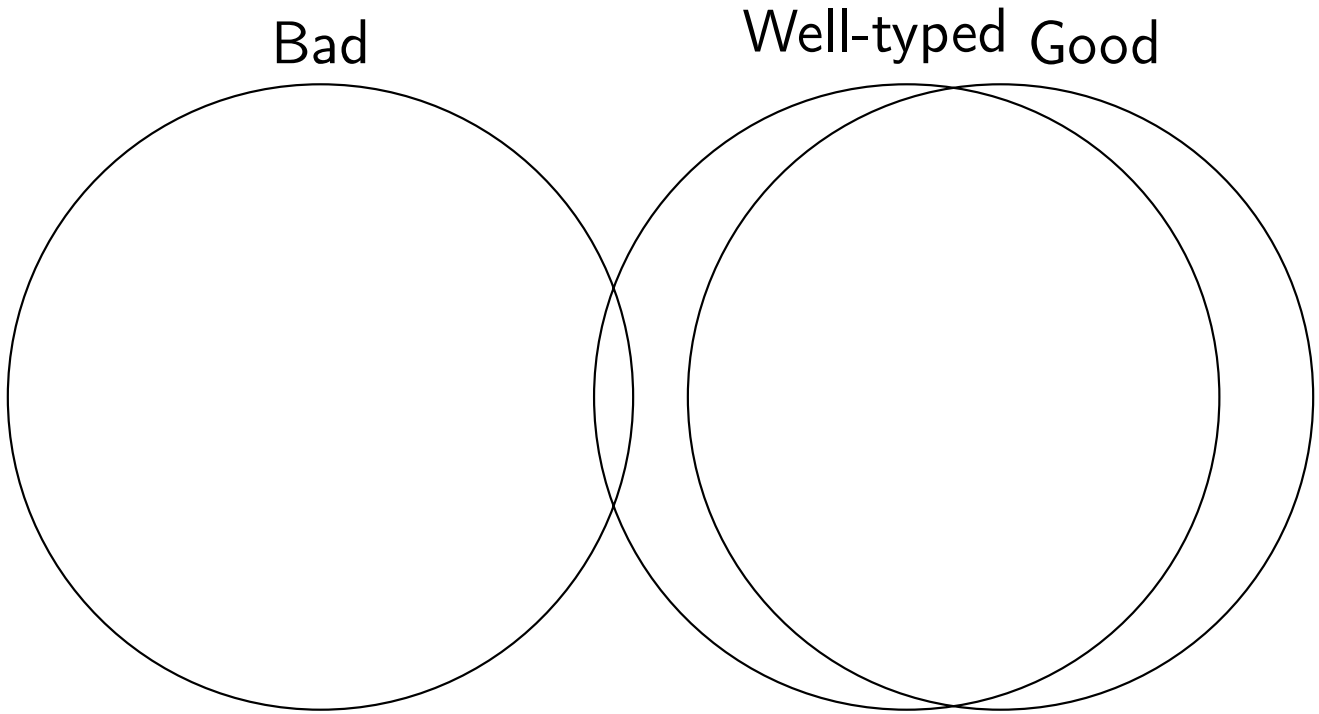
Types in programming



Stronger types, safer code



Write more programs



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- Type systems achieve greater and greater expressiveness
- More and more, we have *interesting computation* in the type system
- Scala's type system is Turing-complete!
- How do these non-trivial types look?

Scala type computation

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```
({type F[A] = Either[A, String]})#F
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```
sealed trait Nat { type Plus[N<:Nat] <: Nat }
trait Zero extends Nat {
  type Plus[N <: Nat] = N
}
trait Succ[N <: Nat] extends Nat {
  type Plus[M <: Nat] = Succ[N#Plus[M]]
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```

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- We can even define a general type-level fold!

Scala type computation

Scala

- A
- C

```
s
t

}
t

}
```

- V

-XKitchenSink

Various Haskell extensions

- Generalized algebraic datatypes

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-XKi

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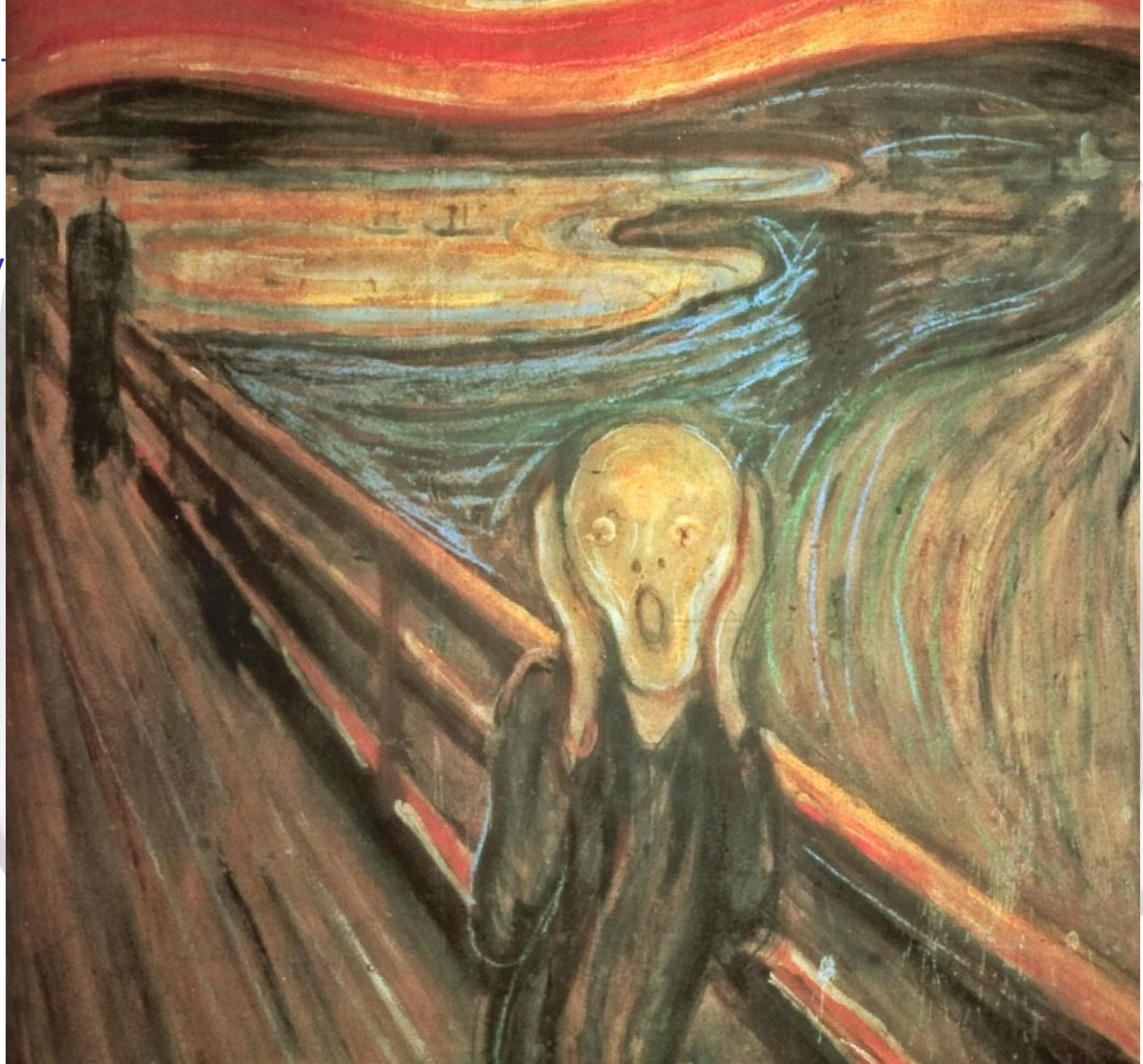

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Why two languages?

Phase distinction

Compile-time computation happens in types and type checking

Run-time computation happens with terms

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Totality and decidability

- We want our compiler to terminate, but not necessarily our programs

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Run-time computation happens with terms

Totality and decidability

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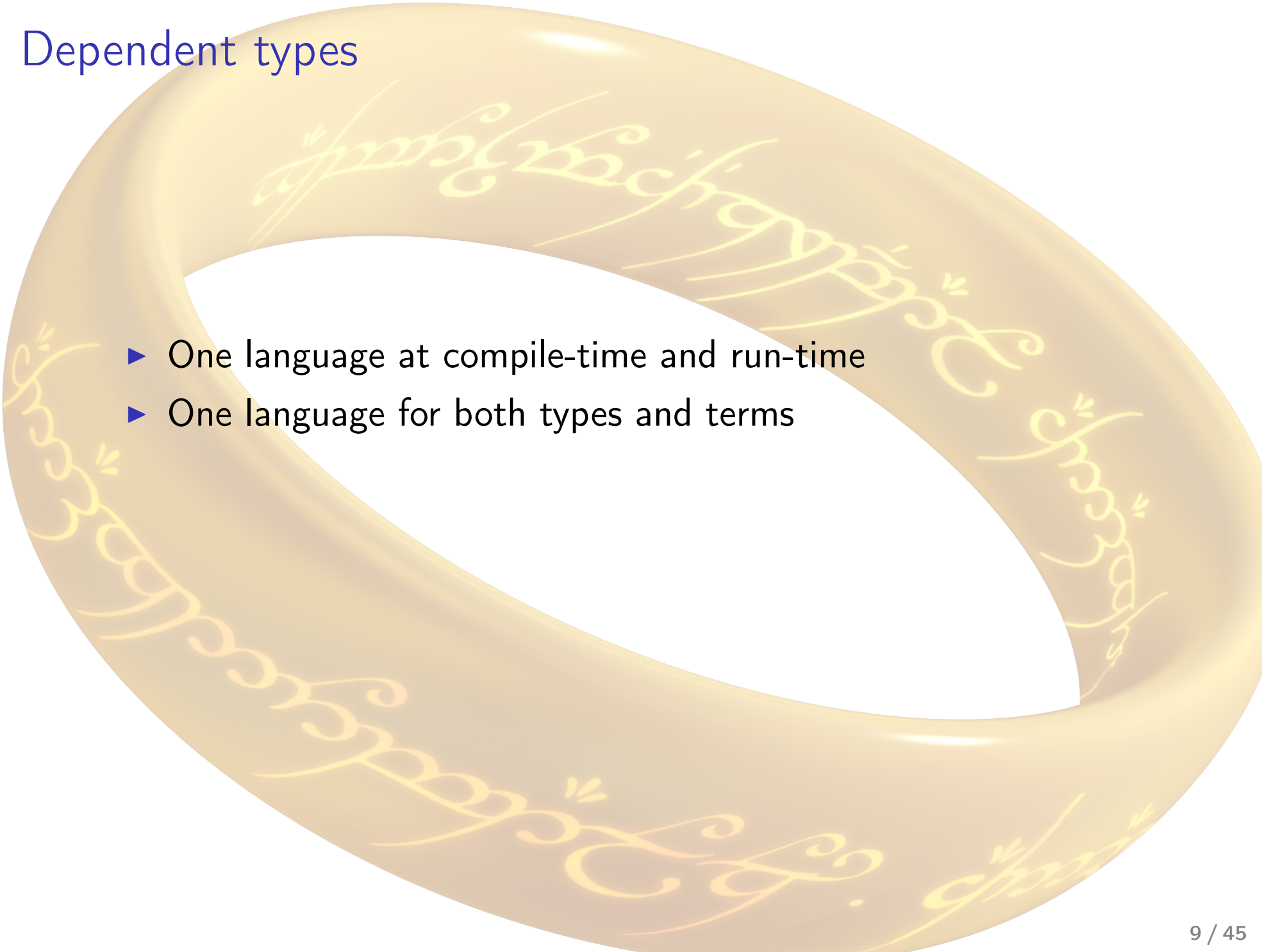
Erasure

Types should disappear at run-time, creating no overhead

Dependent types

- One language at compile-time and run-time

Dependent types



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- One language for both types and terms

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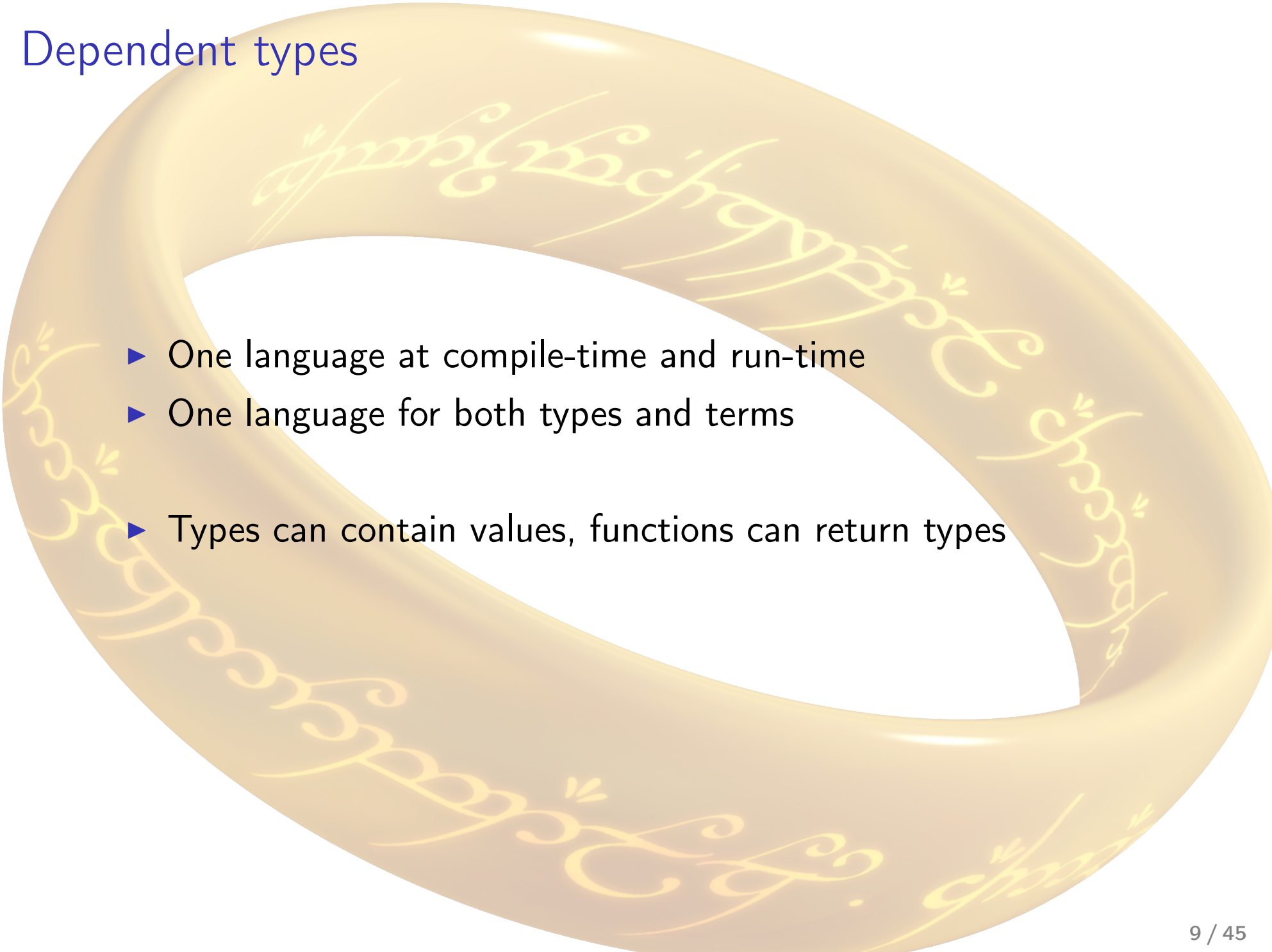

- One language at compile-time and run-time
- One language for both types and terms

- Types can contain values, functions can return types

Overview

Idris

- Pure functional programming language
- Full dependent types
- Compiles to C, LLVM, Java, Javascript (browser and Node)
- Syntax inspired by Haskell
- Strict evaluation order
- Extensible syntax
- Integrated theorem proving
- Free software - everything is on Github

Your presenter

- PhD student at ITU with Peter Sestoft
- Currently visiting Chalmers in Gothenburg
- Interests include dependently typed programming, DSLs, and programming tools more generally
- Working on the Actulus project, making a DSL for actuaries
- Contributor to Idris, esp. type providers + usability work
- Grew up in Moscow, Idaho, USA, but lived in Copenhagen since 2005
- `http://www.itu.dk/people/drc`

Demonstration

Idris basics: Hello, world!, natural numbers and lists; vectors; first dependent types

Dependent Pattern Matching

- Pattern matching one argument can affect other arguments (through unification)

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Demo: zip reconsidered; take and drop on vectors

The with rule

- Sometimes recursive calls should affect our arguments
- The `with` rule lets us express this instead of using `case`
- This can implement custom views

Demonstration

Snoc lists as a view of regular lists

AVL Trees

AVL trees are balanced binary trees where the heights of the child branches differ by at most 1

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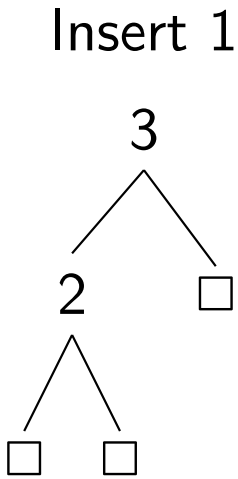
Tree rotations are used to recover the invariant when inserting



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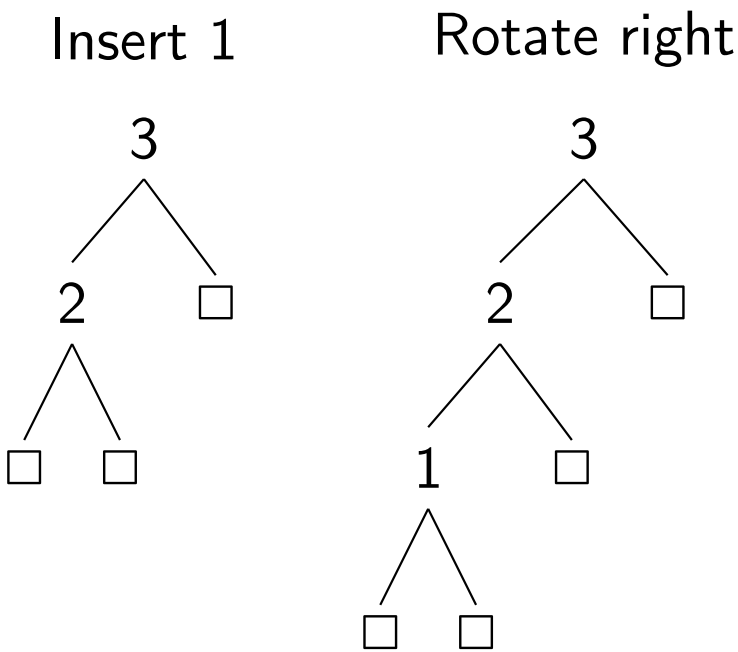

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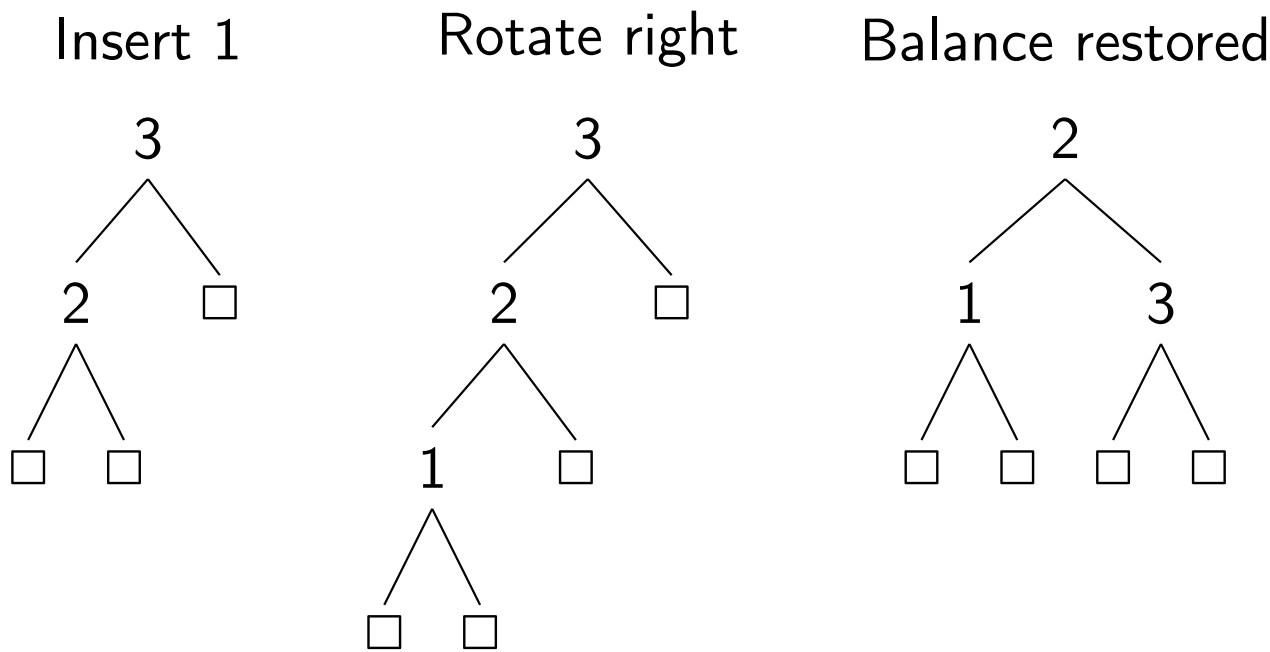


Demonstration: AVL trees with static balance invariant

Universes

A universe is:

- A datatype whose elements describe a collection of types (*codes*)
- An function that interprets the codes as real types
- Examples: types that are serializable by some algorithm

Demo: `Universes.idr`

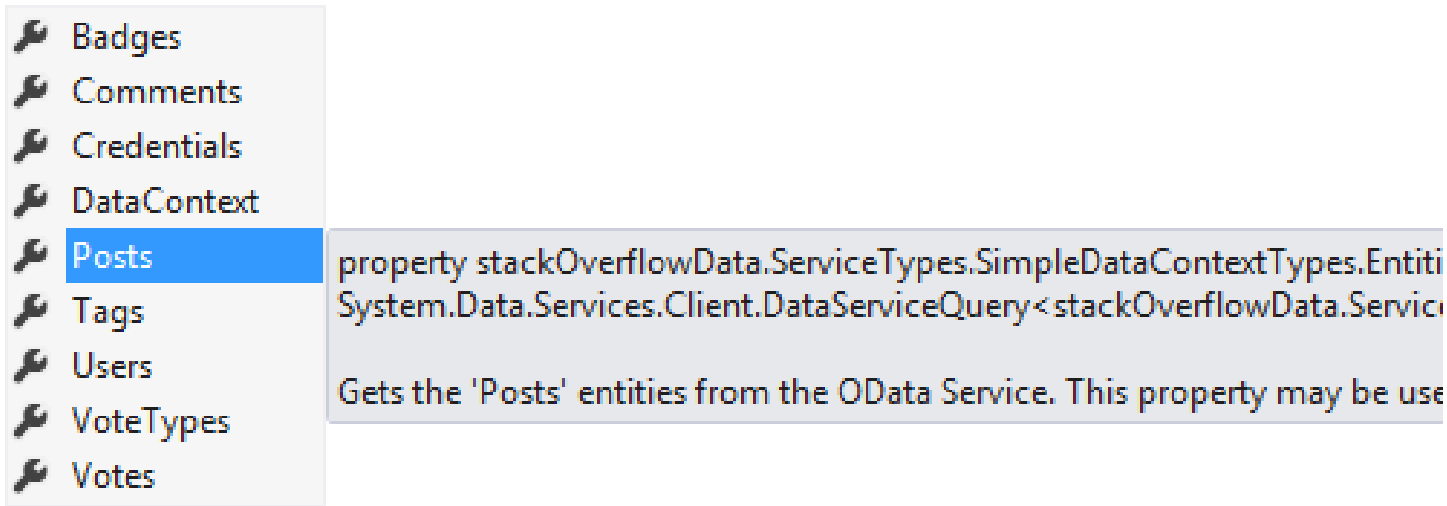
Well-Typed Interpreter

Using a universe of simple types, get Idris to show the type-correctness of an interpreter for the lambda calculus.

F# type providers

```
module SO =
    type stackOverflowData =
        ODataService< @"http://data.stackexchange.com/stackoverflow/atom">
    let context = stackOverflowData.GetDataContext()

    context.
```




```
    let tpQuestionCount = query {
        for post in context.Posts do
        where (post.Tags.Contains("f#") && post.Body.Contains("type provider"))
```

Limitations

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- Type providers must be developed in separate modules

Idris Type Providers

- Types are terms like any other

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- We have a means of producing terms from I/O: **execution**.

Simple Example

```
fromFile : String -> IO (Provider Type)
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fromFile fname =
  do str <- readFile fname
     let type = if (trim str) == "Int"
                   then Int else Nat
     return (Provide type)
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%provide (T1 : Type) with fromFile "theType"
foo : T1
foo = 3
```

Errors

```haskell
data Provider a = Error String
                | Provide a
```

Errors

```
confirmAge : IO Bool
confirmAge =
  do putStrLn "How old are you?"
     input <- getLine
     let age = parseInt (trim input)
     case age of
       Nothing => do putStrLn "Didn't understand"
                     confirmAge
       Just x => return (x >= 18)
```

Keep off my lawn!

```
adultsOnly : IO (Provider Bool)
adultsOnly =
  do oldEnough <- confirmAge
     if oldEnough
       then do putStrLn "ok"
               return (Provide True)
       else return (Error ("Only adults may " ++
                           "compile this program"))

%provide (ok : Bool) with adultsOnly
```

Demo

How does it work?

```
data SQLiteType = TEXT | INTEGER | REAL
                       | NULLABLE SQLiteType

interpSql : SQLiteType -> Type
interpSql TEXT = String
interpSql INTEGER = Integer
interpSql REAL = Float
interpSql (NULLABLE x) = Maybe (interpSql x)
```

How does it work?

```
data Attribute = (:::) String SQLiteType
```

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data Schema = Nil | (::) Attribute Schema
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data Row : Schema -> Type where
  Nil : Row []
  (::) : (interpSql t) -> Row s -> Row ((col:::t) :: s)
```

How does it work?

```
data DB : String -> Type where
  MkDB : (dbFile : String) ->
         (dbTables : List (String, Schema)) ->
         DB dbFile
```

How does it work?

```
data Query : DB f -> Schema -> Type where
  Select : {db : DB f} -> Tables db s ->
           Expr s INTEGER ->
           (s' : Schema) ->
           {ok : SubSchema s' s} ->
           {auto solveIt : decSubSchema s' s = Yes ok} ->
           Query db s'
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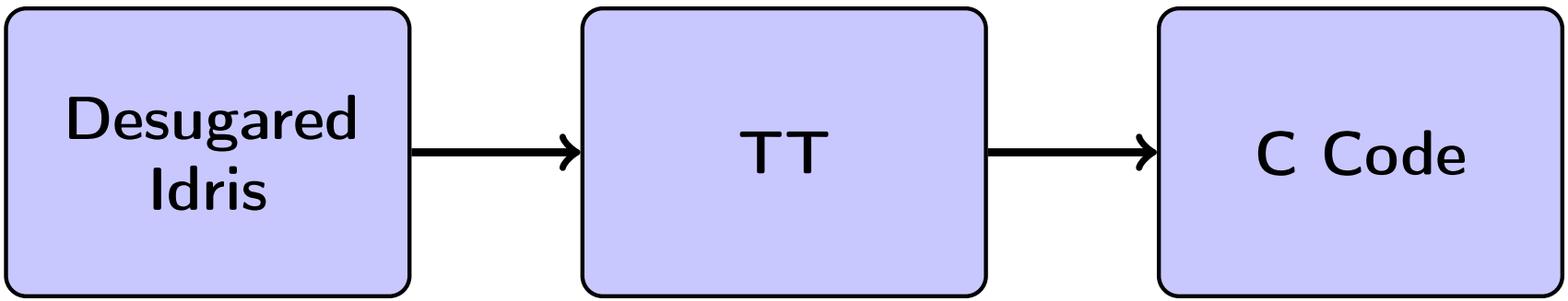
syntax SELECT [schema] FROM [tables] WHERE [expr] =
  Select tables expr schema
```

The Type Provider

- Query the DB for the schemas
- Parse the DDL
- Return a `DB`

Elaboration



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3. Execute π:
   - If `Provide` y, then result is $\mathtt{x} : \tau$; $\mathtt{x} = y$.
   - If `Error` *err*, then show user *err*.
   - If something else, then show user a generic error.

Executor

- Interprets IO actions
- Separate from type checker's evaluator
- Must be careful about strictness

Advantages

- Maintain Idris's abstractions and safety properties
- Develop type providers as ordinary programs
- Define and use type providers in same module

Disadvantages

- Cannot introduce identifiers — inconvenient!
- No laziness
- Record types must be “faked”
- Terrible error messages

Next Steps

- Lazy type providers

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- Foreign function interface generation

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- Lazy type providers
- Foreign function interface generation
- Alternate execution times

More on Idris Type Providers

- David Raymond Christiansen. *Dependent Type Providers*. WGP '13.
- David Raymond Christiansen. *Looking Outward: When Dependent Types Meet I/O*. M.Sc. thesis, IT University of Copenhagen, 2013.

Not Covered (but feel free to ask))

- Type classes
- Effects
- Idiom brackets and bang bindings
- Proof automation
- Optional laziness
- Codata and corecursion

Resources

- `http://www.idris-lang.org/`
- `http://groups.google.com/group/idris-lang`
- IRC: `#idris` on freenode
- `https://github.com/idris-lang/Idris-dev/wiki`
  - In-progress manual
  - Installation help
- `https://github.com/idris-hackers/`
  - Editor modes
  - Miscellaneous libraries
  - Other utlities such as IRC bots

Get Involved!

Good projects for beginners:

- Documentation
- Port your favorite library
- Polish
- Document the pain points experienced by new users
- Improve editor and tool support

Hackathon!

There will be an Idris developers' meeting in Gothenburg next month.

Tuesday, 29 April Introductions to Idris for Haskell and Agda programmers

Wednesday-Friday Talks, projects, and productivity

Sign up by mailing `drc@itu.dk`, details on wiki on Github