Translating Scala Programs to Isabelle/HOL

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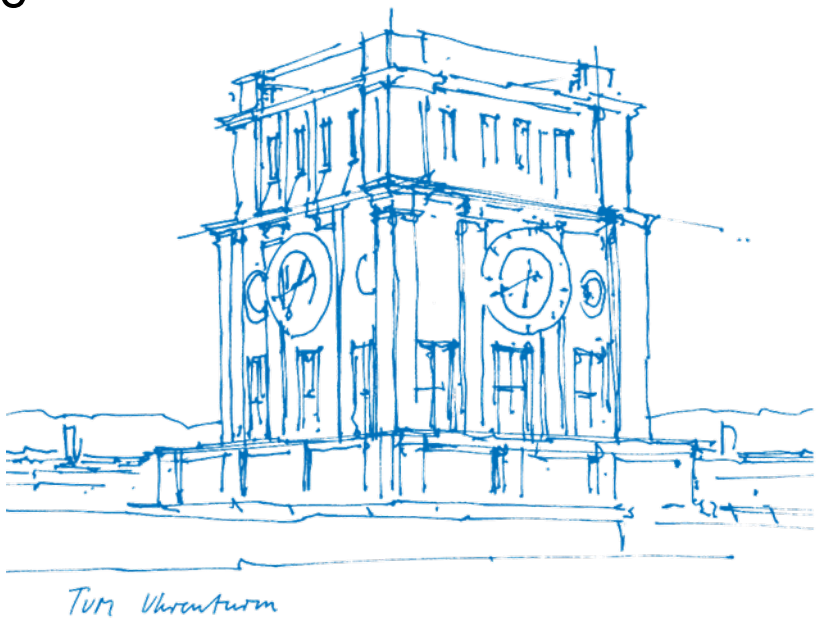

A Taste of Scala & Isabelle

Scala

- functional & object-oriented language
- initially developed at EPFL by Martin Odersky

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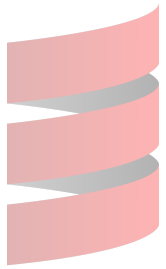
- runs on JVM, Javascript and LLVM
- strong industry support

Scala Example

```
sealed abstract class List[A]
case class Cons[A](head: A, tail: List[A]) extends List[A]
case class Nil[A]() extends List[A]

def size[A](l: List[A]): BigInt = l match {
  case Nil() => BigInt(0)
  case Cons(_, xs) => 1 + size(xs)
}
```



Isabelle

- interactive proof assistant
- powerful automation

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- interactive proof assistant
- powerful automation
  - classical and equational reasoning
  - decision procedures (e.g. linear arithmetic)
  - integration with external automated theorem provers
  - ...

Isabelle/HOL

- *LCF* tradition: small proof kernel

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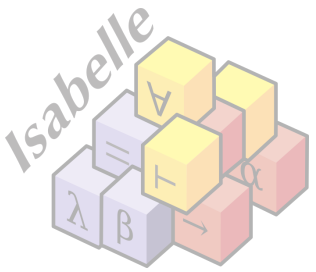
- most prominent logic: *HOL*
  - offers commands for functional programming
  - recursive functions, datatypes, ... are definitional

Isabelle/HOL Example

datatype α list $=$ Nil $|$ Cons α (α list)

primrec size :: α list $\Rightarrow$ int **where**
  size Nil $= 0$
$|$ size (Cons x xs) $= 1 +$ size xs



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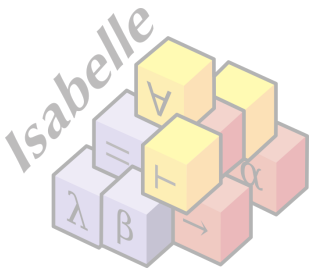
lemma size $xs \geq 0$
by (induct xs) simp+



Leon

A Verification & Synthesis Toolkit for Scala

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}) ensuring(_ >= 0)
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Leon Undo Redo Link Console Params About Documentation WebBuilder Login

```
1  import leon.lang._
2
3  object Example {
4
5    sealed abstract class List[A]
6    case class Cons[A](head: A, tail: List[A])
7      extends List[A]
8    case class Nil[A]() extends List[A]
9
10   def size[A](l: List[A]): BigInt = (l match {
11     case Nil() => BigInt(0)
12     case Cons(_, xs) => 1 + size(xs)
13   }) ensuring(_ >= 0)
14
15 }
16
```

Load an example

-- Select an example

Analysis Compiled ✔

Function	Inv.	Verif.
Style	?	✔
apply	?	✔
ensuring	?	✔
size	?	✔

Bridging the Gap

Bridging the Gap

... but why?

Motivation

Isabelle brings a lot to the table ...

- 20+ years of development
- 1M+ lines of libraries
- trustworthiness through LCF approach
- rich specification & proof language

Motivation

Leon brings a lot to the table ...

- readily-available verification for a wide-spread language
- Goal: Introduce developers to formal methods?

Bridging the Gap

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... with as little unverified code as possible

Bridging the Gap

Problem

- Input: Scala AST
- Translation: ???
- Output: Isabelle ???

Possible solution

Textual code generation

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Talk directly to Isabelle's API

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  - supports Java & Scala
  - can be used like an asynchronous RPC library
  - setup-free

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  - can be used like an asynchronous RPC library
  - setup-free
- can be used for other projects
- still: manual work required

Translating Datatypes

Datatypes are almost straightforward.

Translating Functions

Scala input

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Isabelle output

```
fun size xs = (case xs of Nil ⇒ 0 | Cons x xs ⇒ 1 + size xs)
```

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Evaluation

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- almost complete

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- almost complete
- ... including gnarly pattern matches
- Isabelle can prove 71% of the verification conditions automatically
- missing: array, string operations
- takes $\approx$ 40 seconds on a fast machine

Reuse

```
sealed abstract class List[T] {

  def size: BigInt = ... // implementation
}

case class Cons[T](h: T, t: List[T]) extends List[T]

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```

Reuse

```
@isabelle.typ(name = "List.list")
sealed abstract class List[T] {
  @isabelle.function(term = "Int.int o List.length")
  def size: BigInt = ... // implementation
}

@isabelle.constructor(name = "List.list.Cons")
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```

Integration

```
@proof(method = "(clarsimp, induct rule: list_induct2, auto)")
def mapFstZip[A, B](xs: List[A], ys: List[B]) = {
  require(length(xs) == length(ys))
  xs.zip(ys).map(_._1)
} ensuring { _ == xs }
```

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  - but: just 3500 lines of code (including verified code)
- user doesn't see resulting terms and definitions
- countermeasure: print *report*
  - looks almost like an Isabelle theory
  - can be copy-pasted into IDE

Conclusion

- prove Scala code correct with high assurance
- co-develop specifications in Isabelle and Scala
- zero setup required, integrates seamlessly
- groundwork for using Isabelle as an API has been laid

Q & A