Sound Reasoning about Integral Data Types with a Reusable SMT Solver Interface

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The Leon Verification System

- Verifier for the Scala language.
- Support a well-defined subset of Scala.
  - A functional core language.
  - Many imperative extensions.
  - Some ways to express non-determinism.
- Complete for finding counterexamples.
- Big project from the LARA group at EPFL, with contributions from many present (and past) members.

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Specifications can be defined using contracts.

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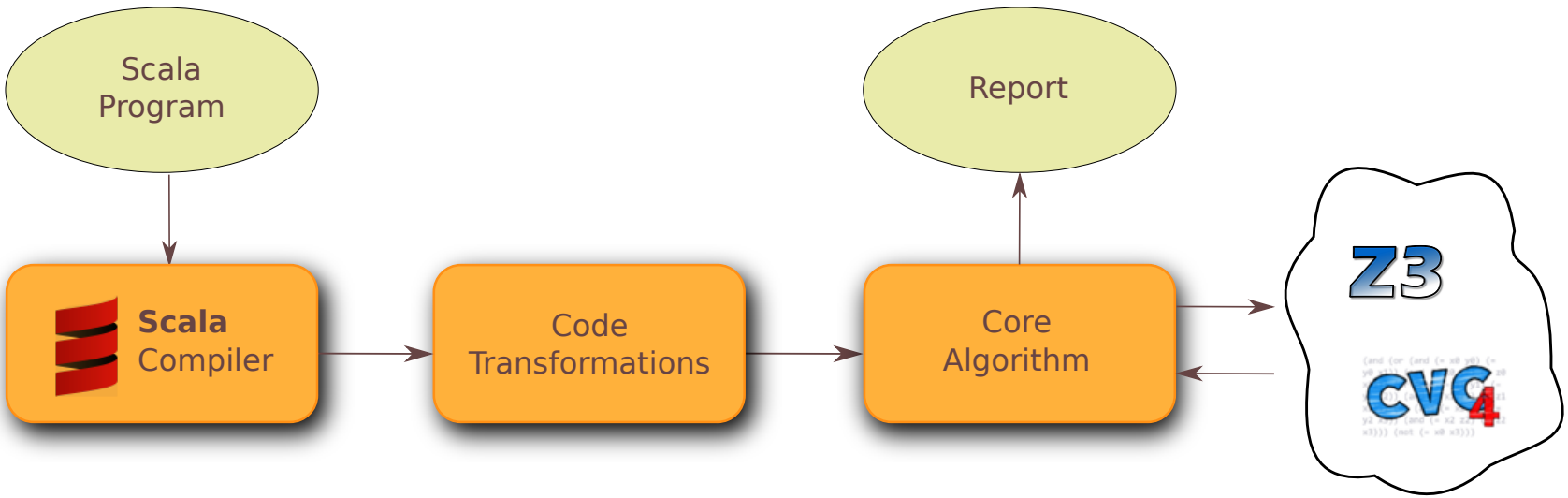
The implementation and specification languages are the same.

Architecture of Leon



Demo

Int and BigInt

Int	Primitive integer type: bit-vector semantics
BigInt	Library type: mathematical integer semantics

- Mathematical reasoning is usually easier with integers.
- Most programs use Int instead of BigInt.
- Easy to ignore the bounded nature of Int.

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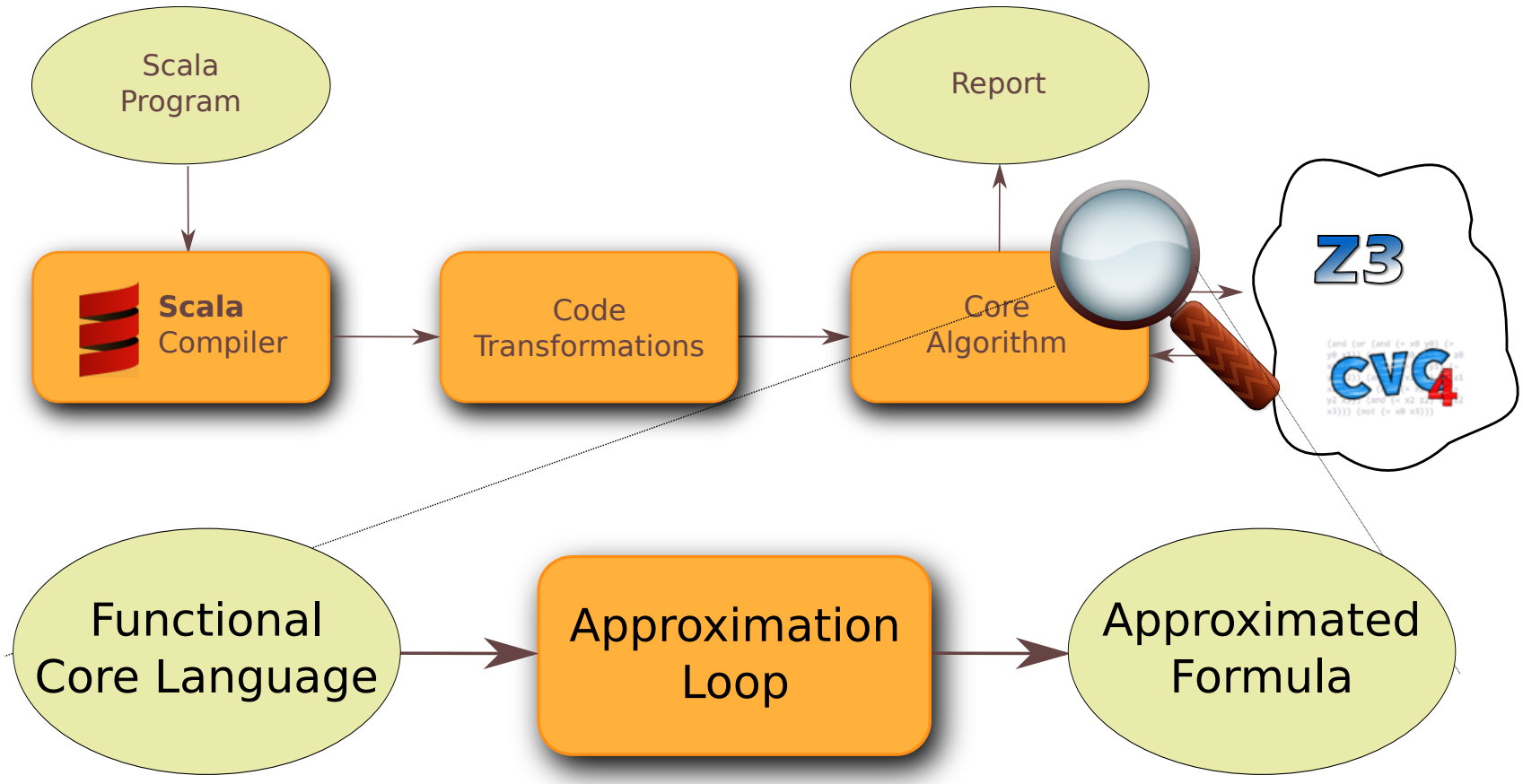
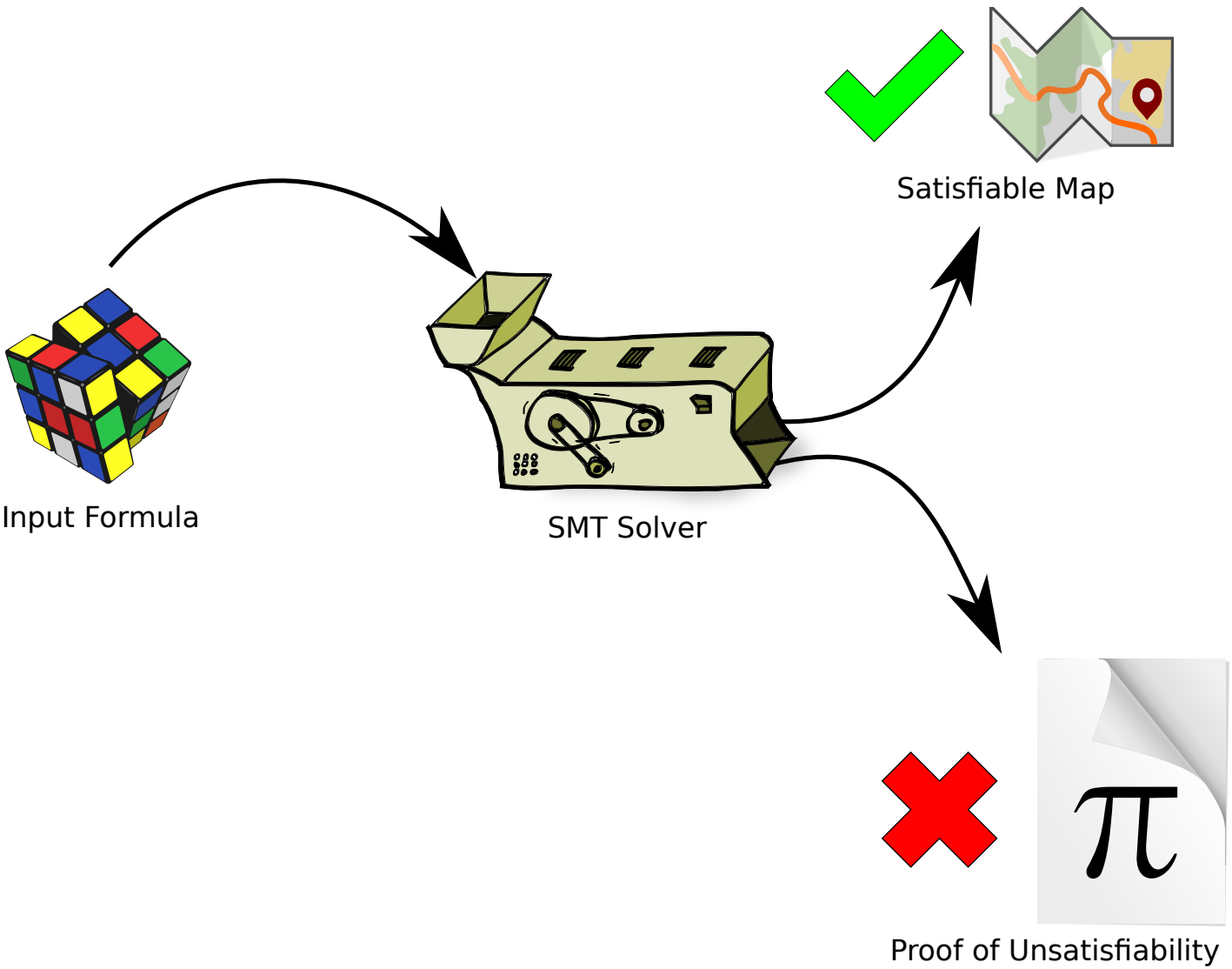
A Closer Look at Leon Unrolling



SMT Solver


Satisfiable Map
Input Formula
SMT Solver
Proof of Unsatisfiability

SMT Solver Theories

Any mathematical theory with a well defined axiomatization.

Of interest to programming languages:

- **Int** Mathematical, unbounded, integers: Corresponds to Scala `BigInt`.
- **BitVector** Fixed, finite-size, bit-vectors: Correspond to Scala `Int`.
- **ADT** Algebraic data types. Models a subset of case classes functionalities.
- **Array** Map from one type to another. Models Scala `Array` and `Map`.
- **UF** Uninterpreted functions. Helps with abstractions.

Many Alternative Implementations

- With so many theories, support varies from solver to solver.
- State-of-the-art algorithms: ongoing research.
- Good to remain as solver-agnostic as possible.

SMT-LIB Interface

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"**SMT-LIB** is an international initiative aimed at facilitating research and development in Satisfiability Modulo Theories (SMT)"

`http://www.smtlib.org`

- Text-based format to standardize communication with SMT solvers.
- Similar to a programming language, but declarative. Syntax based on Lisp.
- Large library of benchmarks. Enable organization of the annual SMT-COMP competition.
- Good support in existing solvers, including Z3 and CVC4.

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Leon: Integration with SMT Solvers

- Leon abstracts away the backend solver.
- One of the implementation generate SMT-LIB commands: get many different solvers essentially for "free"
- The SMT-LIB interface is exposed in a stand-alone Scala module.

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`scala-smtlib` is a lightweight abstraction on top of the SMT-LIB standard.

`https://github.com/regb/scala-smtlib`

- Simple, type-safe, communication with SMT solvers.
- Support for the latest SMT-LIB 2.5 standard.
- Include a fully complient parser (not used in Leon) that can help building applications with SMT-LIB as input.

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Conclusion

Extensions to the Leon system

- Sound reasoning about integral data types: `Int` and `BigInt`.
- Solver-agnostic backend with the help of an open-source SMT-LIB Scala library.

Work in progress

Optimization of BigInt

- When writing program, `BigInt` is often closer to the expected meaning than `Int`.
- However can often be two order of magnitude slower.
- Why not proving bounds statically on code using `BigInt` and compiling to equivalent and faster `Int`.

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