Smten: Automatic Translation of High-level Symbolic Computations into SMT Queries

Richard Uhler[1], Nirav Dave[2]

[1] Massachusetts Institute of Technology, Computer Science and Artificial Intelligence Laboratory, Cambridge, MA, USA, ruhler@csail.mit.edu

[2] SRI International, Computer Science Laboratory, Menlo Park, CA, USA, ndave@csl.sri.com

Smten: A Meta-Tool

For *developing* SMT-based tools

Developer directly expresses high-level translation concerns

Smten automatically generates optimized translation

Leads to flexible, high performance SMT-based tools with greatly reduced developer effort

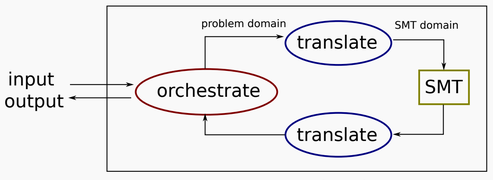
In our case study, Smten reduced lines of code by a factor of 20 while achieving performance comparable to hand crafted translation

Motivation: SMT-Based Tools

Leverage Satisfiability Modulo Theories (SMT) solvers for computer aided verification tasks

Uses include:

- model checking
- program synthesis
- automated theorem proving
- automatic test generation
- software verification



SMT-Based Tool

Challenge: The Translation to SMT

High-level concerns in translation:

- What SMT solver should be used?
- How should high-level structures be represented in SMT?
- How should problem be decomposed into queries?

Implementing translation is tedious and error-prone

Optimized translation is crucial to a high-performance SMT-based tool:

- Generating large formulas is costly
- Transmitting large formulas to an SMT solver is costly

The Smten Language

Unified language for orchestration and symbolic computation

High-level, purely functional

Syntax and features borrowed heavily from Haskell

- Algebraic data types
- polymorphism
- general purpose input/output
- pattern matching
- type classes

Provides a primitive API (based on monads) for describing symbolic computations

Example: Translating String Constraints

High Level Problem:

```
var v : 4;
val v' := concat("f", v);
assert v' contains "foo";
assert v' contains "odd";
assert v' not contains "weird";
```

Translation concerns:

How to represent

- strings?
- chars?

Generated SMT Formula:

Represent char as bit vector

Variables: v1, v2, v3, v4 of type Bit #8

Use naming variable naming convention

Formula:

```
( (102 = 102 ∧ v1 = 111 ∧ v2 = 111)
∨ (v1 = 102 ∧ v2= 111 ∧ v3 = 111)
∨ (v2 = 102 ∧ v3 = 111 ∧ v4 = 111) )
```

Map char equality to bitvector equality

```
∧ ( (102 = 111 ∧ v1 = 100 ∧ v2 = 100)
∨ (v1 = 111 ∧ v2 = 100 ∧ v3 = 100)
∨ (v2 = 111 ∧ v3 = 100 ∧ v4 = 100) )
```

Should optimize away in translation!

```
∧ (¬ (102 = 119 ∧ v1 = 105 ∧ v2 = 101 ∧ v3 = 114 ∧ v4 = 100))
```

Result: SAT with v1 = 111, v2 = 111, v3 = 100, v4 = 100

Corresponds to v' = "foodd"

High-level Problem in Smten:

Specify SMT solver

Char representation

```
main = do
  result <- runSymbolic STP $ do
     v <- sequence (replicate 4 (free :: Symbolic (Bit #8)))
     let v' = fromStr "f" ++ v
     assert (contains v' (fromStr "foo"))
     assert (contains v' (fromStr "odd"))
     assert (not (contains v' (fromStr "weird"))
     return v'
  case result of
     Just x -> putStr $ "SAT: " ++ show (toStr v')
     Nothing -> putStr $ "UNSAT"
```

Case Study: Hampi

An existing SMT-based tool for solving string constraints

Has been successfully applied to testing and analysis of real programs:

- Analyses for SQL injections in web applications
- Automated bug finding in C programs

Implemented in Java, using STP SMT solver

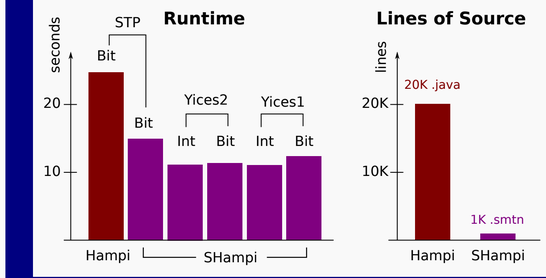
SHampi

A re-implementation of the Hampi tool using Smten

Easily expressed high level optimizations used in Hampi:

- Fixed sizing of CFGs
- Caching of submatch results

We explored 3 SMT solvers and 2 representations for characters



References

Kiezun, A., Ganesh, V., Guo, P.J., Hooimeijer, P., Ernst, M.D.: Hampi: a solver for string constraints. In: Proceedings of the 18th international symposium on Software testing and analysis. ISSTA '09, New York, NY, ACM (2009) 105-116

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