Bonus Topics: Automated Reasoning, Runtime Verification

http://d3s.mff.cuni.cz

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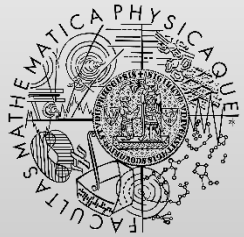

FACULTY OF MATHEMATICS AND PHYSICS
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Automated Reasoning

- SAT solvers
- SMT solvers
- Theorem provers

SAT solvers

- Domain: propositional logic
  - Formulas over boolean variables
- Tools
  - MiniSAT (http://minisat.se/)
  - Lingeling (http://fmv.jku.at/lingeling/)
  - Glucose (https://www.labri.fr/perso/lsimon/glucose/)
- Applications
  - Hardware & software verification (testing)
  - Efficiently solving various problems encoded to SAT

SMT solvers

- Domain: first-order predicate logic with specific theories and other restrictions
  - Formulas include predicates and functions
    - arithmetic expressions (+, -)
    - relational operators (=, >, <)
  - Theories: linear arithmetic, bitvectors, arrays, strings
  - Restrictions: limited support for quantifiers

- Tools
  - Z3 (https://github.com/Z3Prover/z3)
  - CVC5 (https://cvc5.github.io/)
  - OpenSMT (http://verify.inf.usi.ch/opensmt)
  - Common input format: SMT-LIB

Theorem proving

- Domain: complete first-order predicate logic
  - Mathematical induction
  - Higher-order logic (HOL)
  - Machine-checked proofs
- Very powerful, but only partially automated
  - Interactive (requires human assistance)
- Input: set of axioms (theory T), general formula ϕ
  - Relevant use case: proof obligations
- Tools: PVS, Isabelle/HOL, Coq

Theorem proving – tools

- PVS
  - https://pvs.csl.sri.com/
- Isabelle/HOL
  - https://isabelle.in.tum.de/
- Coq
  - https://coq.inria.fr/

PVS – introduction

- Download from https://pvs.csl.sri.com/downloads.html and install
  - Version: PVS 7.1, Linux allegro 64-bit
  - How: unpack & run `install-sh`
- Running: `./pvs`
- Important commands
  - Quit the PVS environment: `Ctrl-x Ctrl-c`
  - Help: `Ctrl-c h` // leave by typing “q”
- Basic guide
  - https://pvs.csl.sri.com/doc/pvs-system-guide.pdf

PVS – usage (commands)

- Opening file: `Ctrl-x Ctrl-f`
- Switch buffer (file): `Ctrl-x b`
- Close buffer: type character “q”

- Demo 1: `sum.pvs`
  - Type checking (show that function is total)
    - Commands: `Alt-x tc`, `Alt-x tcp`
  - Proving main theorem semi-automatically
    - Approach: traverse all branches in the proof tree
    - Start by PVS command: `Alt-x pr`
    - Relevant prover commands: `(induct “n”)`, `(expand “sum”)`, `(assert)`, `(skolem!)`, `(flatten)`

- Demo 2: `stacks.pvs`
- Demo 3: `fm99/phone_1.pvs`

Theorem proving – other tools

- The KeY Project
  - https://www.key-project.org/
- ACL2
  - https://www.cs.utexas.edu/users/moore/acl2/
- Lean
  - https://leanprover.github.io/

Related courses

- Decision Procedures and Verification (NAIL094)
  - http://ktiml.mff.cuni.cz/~kucerap/satsmt/index-en.php
- Formal Mathematics and Proof Assistants
  - NMMB568, LS 2022/23, Department of Algebra

Runtime verification

- Monitors
  - Recording interesting events
    - field accesses, method calls, thread synchronization
  - Checking functional correctness properties defined as finite state machines
- Further details
  - https://en.wikipedia.org/wiki/Runtime_verification
- State of the art: conference RV
  - https://runtime-verification.github.io/events/