Discussion of refinement-based approach

- Advantages:
  - quite close to programming language and programmer
  - special IDEs for programs, specifications and proofs
  - can smoothly integrate powerful logics and dedicated automated techniques
- Disadvantages:
  - expensive solution
  - not very flexible w.r.t. extensions
  - meta-logical aspects cannot be handled

Subsection 8.5.3

Extended static checking

General approach

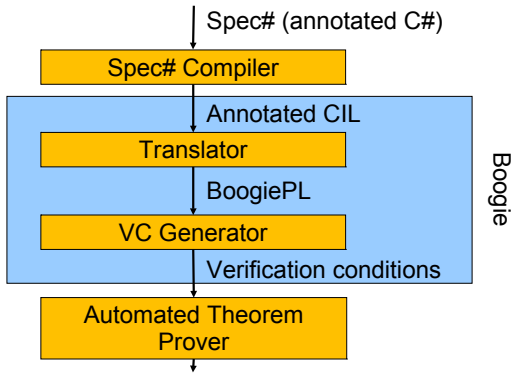
- Programming-language-specific front end/development environment
- Programming-language-specific specification language
- Verification condition generator (VCG)
- Automated prover to discharge the VCs

Example systems

- Spec#: `research.microsoft.com/en-us/projects/specsharp/`
  - programming and specification language: Spec# (extension of C#)
  - specific focus on modularity of specifications
  - uses first-order ATP
  - also supports dynamic checking
- VeriFast: `people.cs.kuleuven.be/~bart.jacobs/verifast/`
  - verifier for single-threaded and multi-threaded C and Java programs
  - pre- and postconditions written in separation logic
  - user guides the proofs by so-called “lemma functions”
  - uses the SMT solver Z3
- BLAST: `mtc.epfl.ch/software-tools/blast/`
  - software model checker for C programs
  - checking temporal safety properties
  - uses **C**ounter**E**xample-**G**uided automatic **A**bstraction **R**efinement
  - succeeds or provides a counterexample or fails

Typical architecture for ESC

Spec# tool architecture:



Discussion of extended static checking

- Advantages:
  - close to programming language and programmer
  - good integration with normal IDEs
  - in principle, no contact with the prover needed
- Disadvantages:
  - specifications less expressive (why?), in particular w.r.t. abstraction
  - error messages can be tricky if checking fails
  - helping the prover can get difficult

Subsection 8.5.4

Specification and refinement

General approach

- Support the formal development from software models to programs
- Relate software models on different levels of abstraction
- Proof refinement properties by generating verification conditions
- Possibly several provers to discharge the VCs (automated and/or interactive)

Example systems

- Event B: www.event-b.org/
  - correctness by construction in the tradition of VDM
  - system = software + environment: represented as transition systems
  - B notation following the Z notation
  - specific development and proof platform Rodin
  - programs are generated from most concrete model
- KIV: www.informatik.uni-augsburg.de/lehrstuehle/swt/se/kiv/
  - formal systems development and interactive verification
  - specification support:
    - functional aspects: abstract data types and HOL
    - state-based aspects: programs and abstract state machines
  - supports various kinds of refinements
  - sophisticated IDE for proof engineering

Discussion

- Software verification goes beyond program verification
- Other interesting aspects:
  - Correctness of software evolution steps
  - Correctness of refactorings
  - Correctness of compilers and programming tools

Subsection 8.5.5

ATP: Automated theorem proving

Techniques for automated verification

A rough classification:

The software verification tools use many techniques for automated proving, in particular:

- Superposition provers (e.g., SPASS, E)
- SMT solvers and model checkers (e.g., Z3, SPIN)
- Abstract interpretation and abstraction refinement