Using Data-flow Analysis to Improve the Scalability of Model Checking

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Project Goal
Unification of Verification and Validation Methods

- Static (data-flow) analysis
- Testing
- Model checking
- Theorem proving
- Runtime Verification
Model checking in one slide

- Method for proving properties of systems
- Suffers from state-space explosion
  - State-space grows exponentially
  - Does not scale for large software systems
- How do you reduce the state-space?
Use data-flow analysis (DFA)

- Less precise but more efficient method for proving properties
- We use DFA to improve model checking

**Diagram:**
- C code → DFA → Model Checker → Result
- Spec
Improving model checking with DFA

- DFA has a number of approximation techniques
  - Context-insensitive analysis
  - Flow-insensitive analysis
  - Path-insensitive analysis

- Approximations improve performance of an analysis
Context-sensitivity

- Context-sensitive
  - Analyze procedure for each call
- Context-insensitive
  - Analyze each procedure once
  - Merge info from all procedure calls
A simple callgraph
Context-sensitive
Key idea

- Identify when context-sensitivity is needed
- Use adaptive analysis [Guyer & Lin 2003]
  - Quick, imprecise analysis
  - Track where precision is necessary
With adaptive analysis
Evaluation

- Measured size of invocation graph
  - Indication of resulting model size
- C code programs
  - ~10Ks lines of code
  - 41 to 959 procedures and library routines
- Results from one security analysis
  - FTP behavior analysis
Motivating results

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<th>Adaptive</th>
<th>Reduction</th>
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Insight

- Two-orders reduction in invocation graph size
  - Upper-bound because DFA adds unrealizable paths
Status & Future Work

- Translating abstracted program to model checker
- Understand relationship with other control abstractions
  - Partial-order reductions
  - Slicing
- Comprehensive integration between DFA and model checking
Questions
Model checking in one slide

- Completely determines satisfiability
- Performs an exhaustive search
- Can generate huge state-space from simple model

- Research focused on reducing state-space by over-abstracting the model
Data-flow analysis in one slide

- Determines safe, but incomplete, solution
- Iteratively solves flow equations
- Quickly converges in practice

- Adaptive analysis can identify where effort should be exerted
Best of both worlds

- Model checking and DFA are two sides of the same coin
- Completeness of model checking
- Scalability of data-flow analysis
## Statement location results

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Current status

- Implementing analysis for C programs
  - Using Broadway/C-Breeze compiler
  - Initial phase limited to typestate problems
- Output model to SPIN model checker
- Handles recursion
Conclusion

- Reduce by two orders of magnitude
  - Without other reduction techniques
- No loss of accuracy in the model check result