Analyzing Robustness of UML State Machines

Steffen Prochnow, Gunnar Schaefer, Ken Bell and Reinhard von Hanxleden

Department of Computer Science and Applied Mathematics
Real-Time Systems and Embedded Systems Group
Christian-Albrecht Universität zu Kiel

MARTES'06, October 2006

Contents

Introduction

Motivation

- realistic Statecharts possess high complexity
    - size
    - side effects
    - misunderstanding
- potential errors can be subtle and hard to locate for humans
- tools provide restricted facilities to avoid modeling errors

Introduction

Motivation

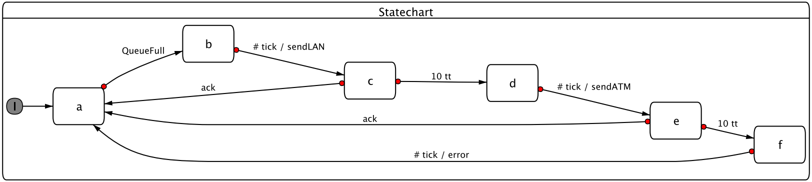
- realistic Statecharts possess high complexity
  - size
  - side effects
  - misunderstanding
- potential errors can be subtle and hard to locate for humans
- tools provide restricted facilities to avoid modeling errors

Purpose

- formulate profiles of robustness rules as a Statechart modeling style guide
- avoid errors, improve readability and maintainability
- establishment of automatic Statechart analysis in a highly configurable tool

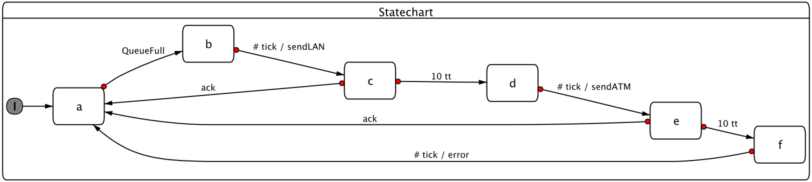
Modeling Errors with Statecharts

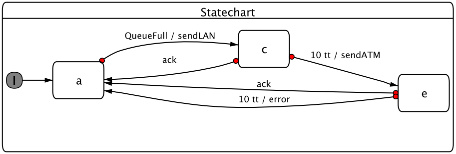
Humans tend to digress, err, and diversify.



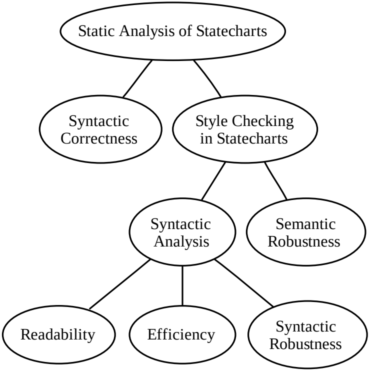
Modeling Errors with Statecharts

Humans tend to digress, err, and diversify.





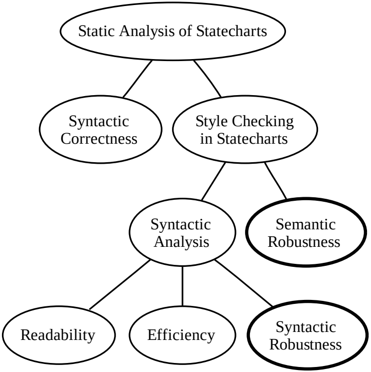
Style Checking in Statecharts



Error prevention:

- human code review
- dynamic testing
- Model Checking
- Style Checking

Style Checking in Statecharts



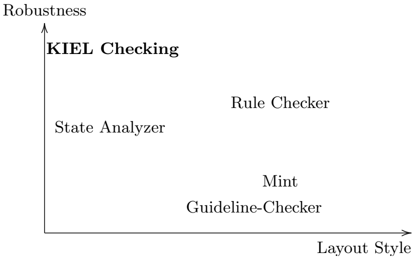
Error prevention:

- human code review
- dynamic testing
- Model Checking
- Style Checking

Statechart Robustness:

- syntactic and semantic style
- gather from element correlation

Style Checking Tools for Statecharts



Mint/Guideline-Checker:

- related to *Matlab/Simulink/Stateflow*
- trivial graphical and syntactic checks

State Analyzer:

- related to *Statemate*
- automated theorem proving
- Problem Specific

Rule Checker:

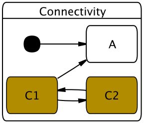
- related to UML
- checking with Java and OCL
- interpreting OCL

A Statechart Style Guide

- operational instructions for humans and configuration for automated analysis
- set of 41 wellformedness-, syntactic, and semantic rules
- defines a subset of the language Statechart

A Statechart Style Guide

- operational instructions for humans and configuration for automated analysis
- set of 41 wellformedness-, syntactic, and semantic rules
- defines a subset of the language Statechart

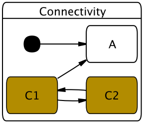


Connectivity

Syntactic Rules

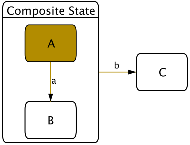
A Statechart Style Guide

- operational instructions for humans and configuration for automated analysis
- set of 41 wellformedness-, syntactic, and semantic rules
- defines a subset of the language Statechart



Connectivity

Syntactic Rules



Overlapping Transitions

Dwelling

Semantic Rules

Checking: The Environment

Kiel **I**ntegrated **E**nvironment for **L**ayout

- modeling environment to explore the visualization and intuitive comprehend complex reactive systems
- provides a simulation based on dynamic focus-and-context
- KIEL's generic concept of Statecharts can be adaptated to specific notations and semantics
- imports, visualizes, and simulates Statecharts created with Esterel Studio, Stateflow, UML tools via XMI format
- Statechart synthesis from textual languages (e. g. Esterel)
- structural Statechart optimization for compactness and readability

Steffen Prochnow and Reinhard von Hanxleden.
Comfortable Modeling of Complex Reactive Systems.
In *Proceedings of Design, Automation and Test in Europe (DATE'06)*, Munich, March 2006.

Steffen Prochnow, Claus Traulsen, and Reinhard von Hanxleden.
Synthesizing Safe State Machines from Esterel.
In *Proceedings of ACM SIGPLAN/SIGBED Conference on Languages, Compilers, and Tools for Embedded Systems (LCTES'06)*, Ottawa, Canada, June 2006.

Checking: The Plug-In

Syntactical Checks/Wellformedness:

- adopted OCL to *KOCL*

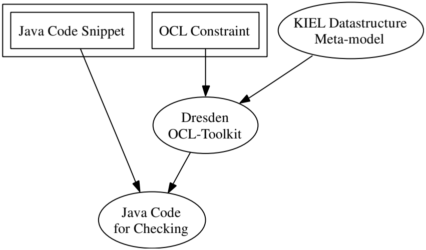
```
rule UML13CompositeStateRule1 {
 declarations {
     message "A composite state can have ...";}
 constraint {
     context ORState or Region;
     "self.subnodes->select(
         v| v.oclIsTypeOf(InitialState))-> size<=1";}
 fails {message;}}
```

Checking: The Plug-In

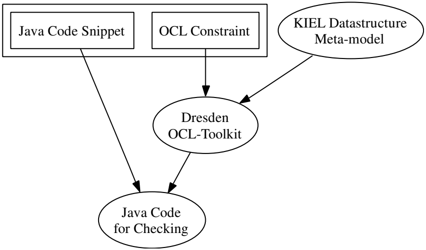
Syntactical Checks/Wellformedness:

- adopted OCL to *KOCL*
- transformation into executable Java code

```
rule UML13CompositeStateRule1 {
  declarations {
      message "A composite state can have ...";}
  constraint {
      context ORState or Region;
      "self.subnodes->select(
          v| v.oclIsTypeOf(InitialState))-> size<=1";}
  fails {message;}}
```



Checking: The Plug-In



Syntactical Checks/Wellformedness:

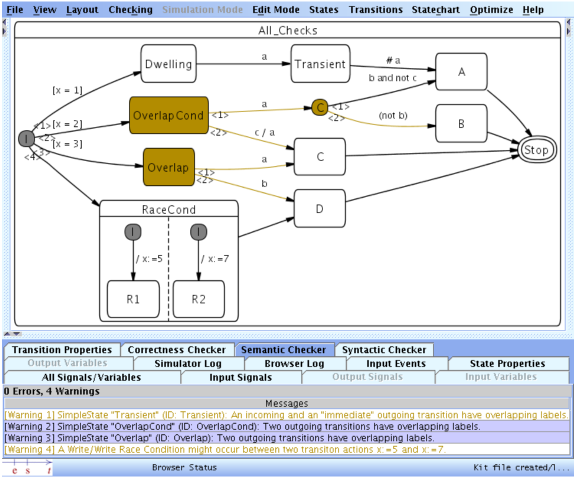
- adopted OCL to *KOCL*
- transformation into executable Java code

```
rule UML13CompositeStateRule1 {
 declarations {
     message "A composite state can have ...";}
 constraint {
     context ORState or Region;
     "self.subnodes->select(
         v| v.oclIsTypeOf(InitialState))-> size<=1";}
 fails {message;}}
```

Semantical Checks:

- using of a theorem prover (CVC Lite)
- e. g. detecting a non-dwelling state: $((e_1 \wedge c_1) \wedge (e_2 \wedge c_2))$
- implementation of JNI communication with SWIG

Demo: Error Checking



Summary & Conclusion

Contributions:

- Comprehensive Statechart Style Guide
- Syntactic and Semantic analyses
- Transformative Approach for OCL usage

Summary & Conclusion

Contributions:

- Comprehensive Statechart Style Guide
- Syntactic and Semantic analyses
- Transformative Approach for OCL usage

Conclusion:

- OCL sufficient for most of our checks
- OCL rule specification is much faster then programming
- OCL doesn't fit all intended Statechart analyses: theorem proving was necessary

Summary & Conclusion

Contributions:

- Comprehensive Statechart Style Guide
- Syntactic and Semantic analyses
- Transformative Approach for OCL usage

Conclusion:

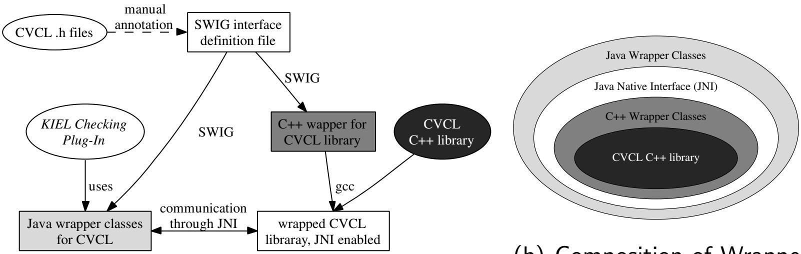
- OCL sufficient for most of our checks
- OCL rule specification is much faster then programming
- OCL doesn't fit all intended Statechart analyses: theorem proving was necessary

We look for **realistic models** to apply our checks!

thanks!

questions or comments?

Appendix: SWIG Workflow

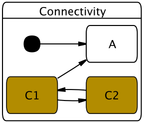


(a) The SWIG Workflow

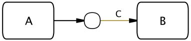
(b) Composition of Wrapper Layers

Figure: Interfacing of *KIEL* and the CVC Lite Library via JNI and SWIG.

Appendix: Further Rules

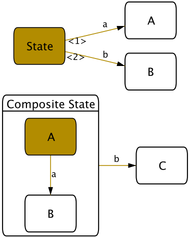


Connectivity



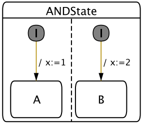
DefaultTransition

Syntactic Rules



Overlapping Transitions

Dwelling



Read/Write Race Condition

Semantic Rules

Appendix: Bibliography

Miltiadis Moutos, Albrecht Korn, and Carsten Fisel.
Guideline-Checker.
Studienarbeit, University of Applied Sciences in Esslingen, June 2000.

Christian Scheidler.
Systems Engineering for Time Triggered Architectures.
SETTA Consortium, 2002.
Deliverable D7.3 – Final Document.

Martin Mutz and Michaela Huhn.
Automated statechart analysis for user-defined design rules.
Technical report, Technische Universität Braunschweig, 2003.

David M. Beazley.
SWIG: An easy to use tool for integrating scripting languages with C and C++.
In *Proceedings of the Fourth Annual USENIX Tcl/Tk Workshop*, pages 129–139, 1996.

Clark W. Barrett and Sergey Berezin.
CVC Lite: A new implementation of the Cooperating Validity Checker Category B.
In Rajeev Alur and Doron A. Peled, editors, *Proceedings of Computer Aided Verification: 16th International Conference, CAV 2004, Boston*, volume 3114 of *Lecture Notes in Computer Science*, pages 515–518. Springer, 2004.

Steffen Prochnow and Reinhard von Hanxleden.
Comfortable Modeling of Complex Reactive Systems.
In *Proceedings of Design, Automation and Test in Europe (DATE'06)*, Munich, March 2006.

Steffen Prochnow, Claus Traulsen, and Reinhard von Hanxleden.
Synthesizing Safe State Machines from Esterel.
In *Proceedings of ACM SIGPLAN/SIGBED Conference on Languages, Compilers, and Tools for Embedded Systems (LCTES'06)*, Ottawa, Canada, June 2006.