Overview

- Translation problem
- Tool used: GReAT
- Algorithm with example
- Summary
The translation problem

Motivation

Hybrid automata
- Mathematical modeling technique
- Formal foundations
- Few real-life examples
- Verification capability

Simulink/Stateflow
- *De facto* prototyping and simulation environment for dynamic systems
  - E.g.: Embedded controllers for automobiles
  - Large legacy libraries
  - No formal verification capability

The translation problem

Simulink/Stateflow Example (Input)

Control level of tank:

- `in_flow` to `v2`
- `v2` to `v3`
- `v3` to `h`
- `h` to `15`
- `15` to `v1`
- `v1` to `in_flow`
The translation problem
Hybrid Automata (Output)

Hybrid Systems:
Dynamic systems with simultaneous continuous and discrete dynamics

Hybrid Automata Example (ref: SAL @ U Penn)

\[ \text{Tank}' = 0 \]
\[ \text{Tank}' = -\text{Tank} + \text{In}_1 - \text{max}(\text{Tank} - 15, 0) \times 3 \]
\[ \text{Tank}' = -\text{max}(\text{Tank} - 15, 0) \times 3 \]
\[ \text{Tank}' = \text{In}_1 - \text{max}(\text{Tank} - 15, 0) \times 3 \]

A = (X, V, flow, inv, init, E, jump, á, syn)
- X: a set of real-valued variables
- V: a set of control modes
- flow: a flow condition over X
- inv: a set of invariant over X
- init: an initial condition
- E: a set of transitions
- jump: a condition for transition
- á: a set of events
- syn: a set of synchronization labels

Background
Metamodels as graph grammars

Simulink/Stateflow metamodel:

Simulink/Stateflow model:

Graph grammar

UML-based metamodels for:
Simulink/Stateflow and HSIF (HA interchange language)
Tool used: GReAT

GReAT: UMT: A Simple Model Transformation Language

1. Pattern specification
   - Pattern variables are typed with their UML classes
   - Cardinality of association-ends is checked
   - Extra (OCL) constraints define guard conditions

2. Graph transformation and rewrite
   - Create new/delete/modify objects
   - Attribute mapping (procedural)
   - "Cross-links": edges between old/new objects
   - Input/output ports: pre-bound pattern variables

3. "High-level" control flow over the rules
   - Port connections imply "data flow" and control flow
   - Hierarchy/Sequencing/Recursion/Branching

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Algorithm

1. Stateflow Part
   1. Convert to StateChart
      1. Create Hierarchical StateChart, flatten it
      2. Determine data dependencies, extend state machines
      3. Prune unreachable states
   2. Convert to HSIF
      1. Create Hybrid Automata, variables
      2. Add transitions with guards

2. Simulink Part
   1. Locate associated Hybrid Automata
   2. Add variables as needed
   3. Derive and add equations

Algorithm

Determine data dependencies, extend state machines
Algorithm
Inferring signals, extending state machines

(a) Initial model
(b) Model after inference
(c) Transferring the transitions
(d) Final Hybrid Automata States

Status, metrics

- A hierarchal Simulink diagram with the following primitives:
  - Continuous: Integrator
  - Math: Product/Sum/Gain/Abs/Min/Max/Signum/Saturate
  - Signal and Systems: Mux/Demux/Ground
  - Source and Sinks: Constant/Workspace variables
  - Nonlinear: Controlled Switch/Manual Switch
- The Simulink diagram can contain any number of Stateflow diagram.
- Stateflow diagram can be hierarchical.
- The Stateflow diagram receives signals from Simulink and can only produce switching signals that control the switches.
- Switches cannot be controlled by any other Simulink block.
- In Stateflow, the switch control action can only be performed in the entry action.

Complexity
- Most algorithms are of polynomial complexity
- Some parts are worst-case exponential:
  - State-splitting
  - Flattening

Size
- Primitive rules: 154
- Complex rules: 43
- C++ code: ~6000 lines
### GReAT in Action

<table>
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<tr>
<th>Problem</th>
<th>Developer</th>
<th>GReAT</th>
<th>Hand code</th>
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<td>KHORUS to GUDML</td>
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### Summary, further work

- Tool integration requires translators that convert models created in one tool into semantically equivalent models in other tools. Translators are essential for design automation... but difficult to build.
- Graph transformations can be used to solve practical translation problems ... if good supporting tools are available.
- Modeling a transformation using GT programs offers an opportunity for reasoning about the transformations --- A great potential area for research.
Background slides

UMT
A Transformation Rule
Rules produce multiple matches: "packets". By default, all packets are consumed by a rule, and new set of packets is produced.

"Blocks" are composite rules, with simple composition semantics.

ForBlocks process single packets.

Tests are conditional control structures built from Cases.

Also supported:
- Recursion
- Non-deterministic execution

A single Case.