Statistical model checking with slimsim

Various random thoughts
Statistical model checking for COMPASS/HASDEL

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Ever growing demand for probabilistic/dependability analysis.

HASDEL: Analysis of hybrid and probabilistic systems, used for space launchers and vehicles.

COMPASS:

- Analysis of timed/hybrid systems;
- Analysis of probabilistic systems;
- **No** analysis of timed and probabilistic systems.
Statistical model checking for COMPASS/HASDEL

Project goal: extend our capabilities to analyze timed and probabilistic systems, avoiding hard- and software failures and improve overall confidence.

Otherwise:

Insert any picture of rather expensive equipment unintentionally exploding here.
Problem: Currently no tools (or algorithms) that support probabilistic analysis of the systems that can be described in the toolset.

Our approach: Use (Monte Carlo) simulation to approximate the system behavior.
Preliminaries

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SLIM

SLIM is a modeling language based on AADL

Example nominal:

```plaintext
device gpsDevice
    features
        measurement : out data port bool default false;
    end gpsDevice;

device implementation gpsDevice.i
    flows
        measurement := true in modes (active);
    modes
        acquisition : activation mode urgent in 20 sec;
        active : mode;
    transitions
        acquisition ->[ within 10 sec to 20 sec ] active;
end gpsDevice.i;
```
Preliminaries

SLIM

SLIM is a modeling language based on AADL

Example error:

```plaintext
error model gpsError
    features
        nok : out error propagation;
    end gpsError;

error model implementation gpsError.i
    events
        transient_fault : error event occurrence poisson 0.001 per hour;
        hot_fault : error event occurrence poisson 0.001 per day;
    states
        ok : initial state;
        transient_failure_prop : error state;
        transient_failure : error state urgent in 400 msec;
        hot_failure_prop : error state;
        hot_failure : error state;
    transitions
        ok -[ transient_fault ]-> transient_failure_prop;
        transient_failure -[ nok within 200 msec to 400 msec ]-> ok;
        ok -[ hot_fault ]-> hot_failure_prop;
        hot_failure -[ @activation ]-> ok;
        transient_failure -[ @activation ]-> ok;
end gpsError.i;
```
Preliminaries

SLIM
A fully formalized language derived from AADL, with support for:

- Timed behavior (clocks, guard and invariants)
- Data flows
- Synchronizing events
- Nonblocking events
- Probabilistic error events
- Component reconfiguration (@activation)
Monte Carlo simulation

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Monte Carlo simulation

A brief intro

Generate samples for a process generating random events. When enough samples are generated, with a certain probability the likelihood of the events can be determined.

In our case: Event = Property true/false. Generating event = Generating path
Randomized simulation

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Non-determinism vs. simulation

Deterministic model: Given a state and input, the target state is *uniquely determined*.

Non-deterministic model: Target is a (possibly uncountably infinite) *set* of states.

Simulation approaches this by means of random number generation (RNG).

The point: The abstract model specifies a set of possible next states, but simulation always yields a single -- in practice deterministic -- result.
Randomized simulation

Random numbers

Approximate non-determinism by random numbers. A choice can be made on what probability distribution to use (or go fully deterministic).

In fact, our RNG implements a (probabilistic) scheduler determining the choice in a probabilistic manner (as opposed to the more conventional minimum and maximum).
Randomized simulation

A note on RNG implementations

It is possible to generate true random numbers (TRNG), but is relatively expensive/slow (2048 random bits in `/dev/random`). Fortunately, pseudo random numbers (PRNG) generally suffice for Monte Carlo simulation. But, please don't use `rand()`, at least for simulation.

Time to generate $2^{28}$ integers:

<table>
<thead>
<tr>
<th>Implementation</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C <code>rand()</code></td>
<td>7.28</td>
</tr>
<tr>
<td>C++ Mersenne twister</td>
<td>7.50</td>
</tr>
<tr>
<td>SFMT</td>
<td>6.10</td>
</tr>
</tbody>
</table>
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Generate steps until property can be determined true or false. For CSL, simple to check for basic state formulae:

• \( M \models a \iff a \) holds true in the current state
• \( M \models \psi \land \phi \iff M \models \psi \land M \models \phi \)
• etc...

For path based formulae (i.e. \( \psi U^{[l,u]} \phi \)), a tri-state approach is used (true, false, `not yet known`).

For the operator \( \Pr_{\text{mc}}(\psi) \), (recursive) simulation is used. Note: slimsim currently does not support nesting.

Special cases: Zeno behavior and deadlocks
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Toolset integration

![Toolset Integration Diagram]

The root component contains ports. Performability results are undefined.
Case study

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Avionics case study
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Probabilities of system failure containing DPUs without (left) and with (right) repair

![Graph showing system failure probabilities over time for different repair strategies.](image)

Legend:
- Progressive
- ASAP
- MaxTime
- Local
Conclusion

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Frame title
Thank you for your attention

Any questions?