Statistical model checking with `slimsim`

Various random thoughts

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Statistical model checking for COMPASS/HASDEL

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.

Statistical model checking for COMPASS/HASDEL

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

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SLIM

SLIM is a modeling language based on AADL

Example nominal:

```
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;
```

SLIM

SLIM is a modeling language based on AADL

Example error:

```
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;
```

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 likelyhood of the events can be determined.

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

Randomized simulation

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Randomized simulation

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:

C rand()	7.28 s
C++ Mersenne twister	7.50 s
SFMT	6.10 s

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Strategies

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Path generation

Generate steps until property can be determined true or false. For CSL, simple to check for basic state formulae:

- $M \models a \Leftrightarrow a$ holds true in the current state
- $M \models \psi \wedge \phi \Leftrightarrow M \models \psi \wedge M \models \phi$
- etc...

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

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

Special cases: Zeno behavior and deadlocks

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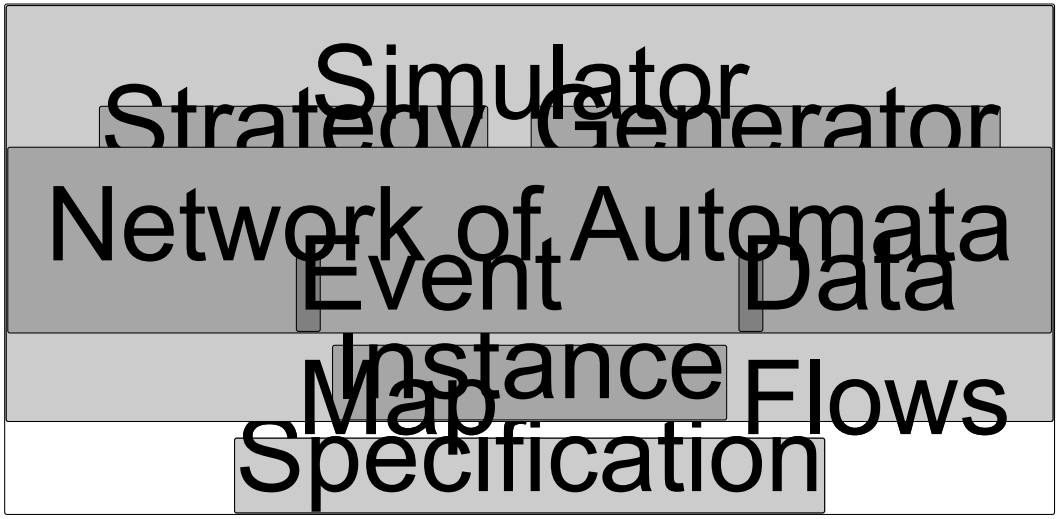
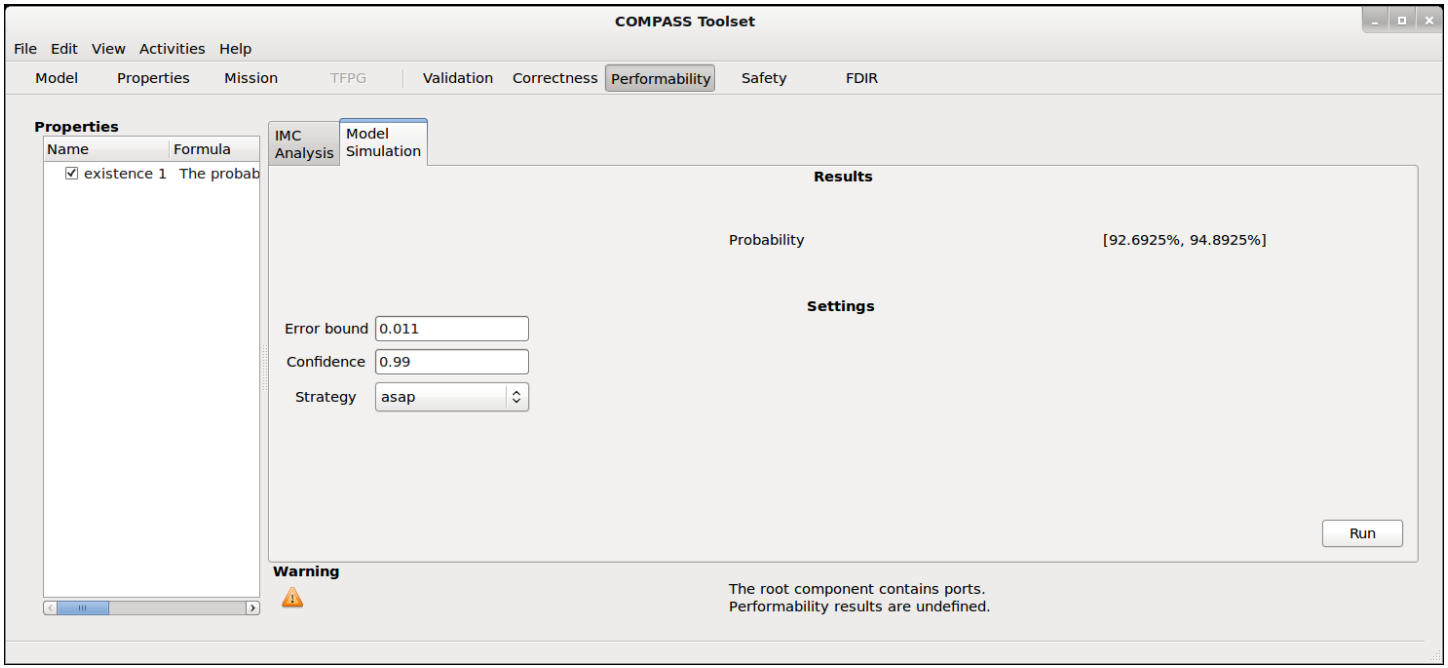
Tool architecture



Toolset integration



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Avionics case study

Experimental results

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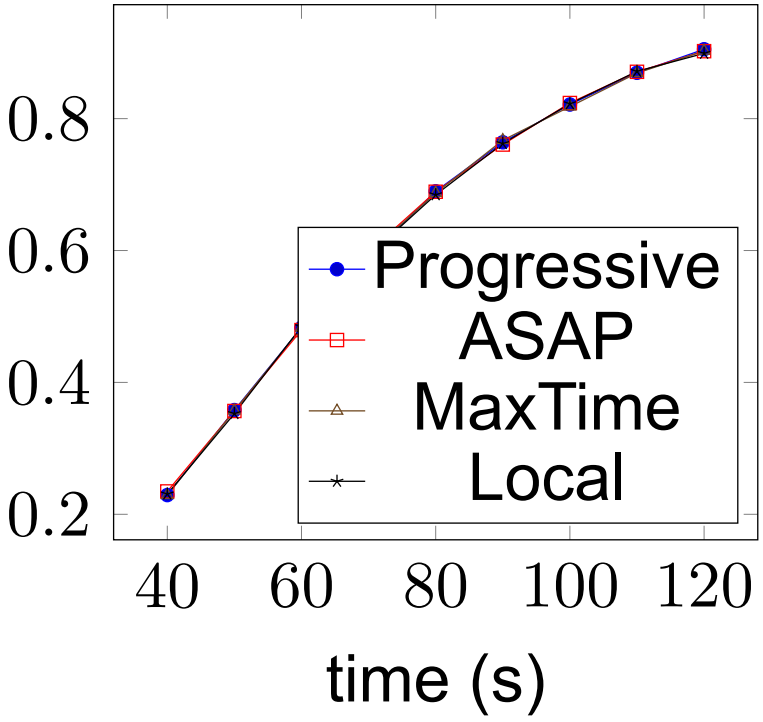
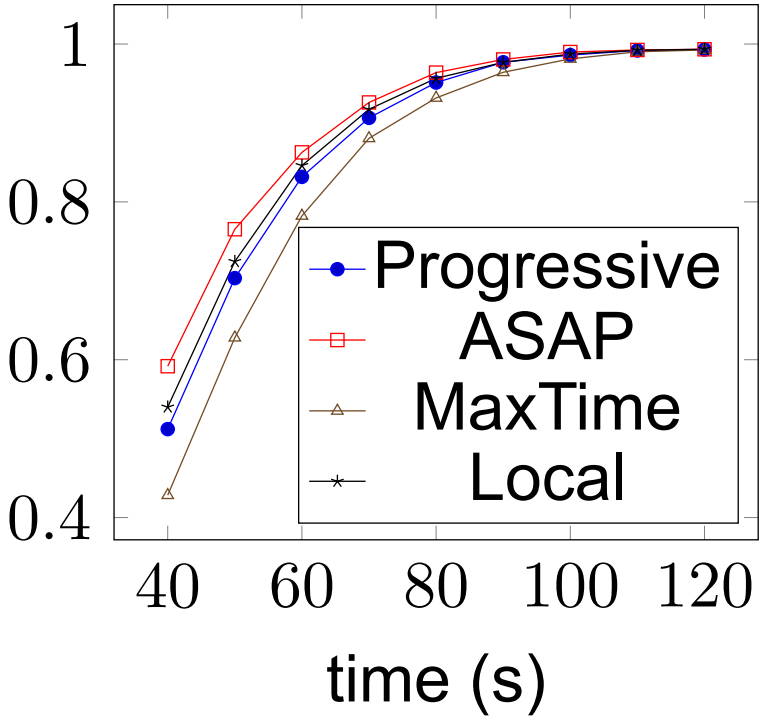
Experimental results

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





Conclusion

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Thank you for your attention

Any questions?