Slicing AADL Specifications for Model Checking

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AADL: Industry Standard for Modeling Embedded Systems

```
system RandomIntValue
 features
  value: out data port int
         default 2;
  update: in event port;
end RandomIntValue;

system implementation
  RandomIntValue.Impl
 modes
  loop: activation mode;
 transitions
  loop -[update then
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Features

- Component-oriented
- HW/SW bindings
- Degraded operations
- Dynamic reconfiguration
- Error handling
- Fault injections
- Timing, probability, hybridity
- Formal semantics

Verification and Performability Evaluation of AADL

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  - (Dynamic) Fault Tree Analysis
  - Fault tolerance evaluation
  - Criticality evaluation
  - Failure modes and effects analysis
  - Fault detection, isolation and recovery
  - Diagnosability
  - Performability

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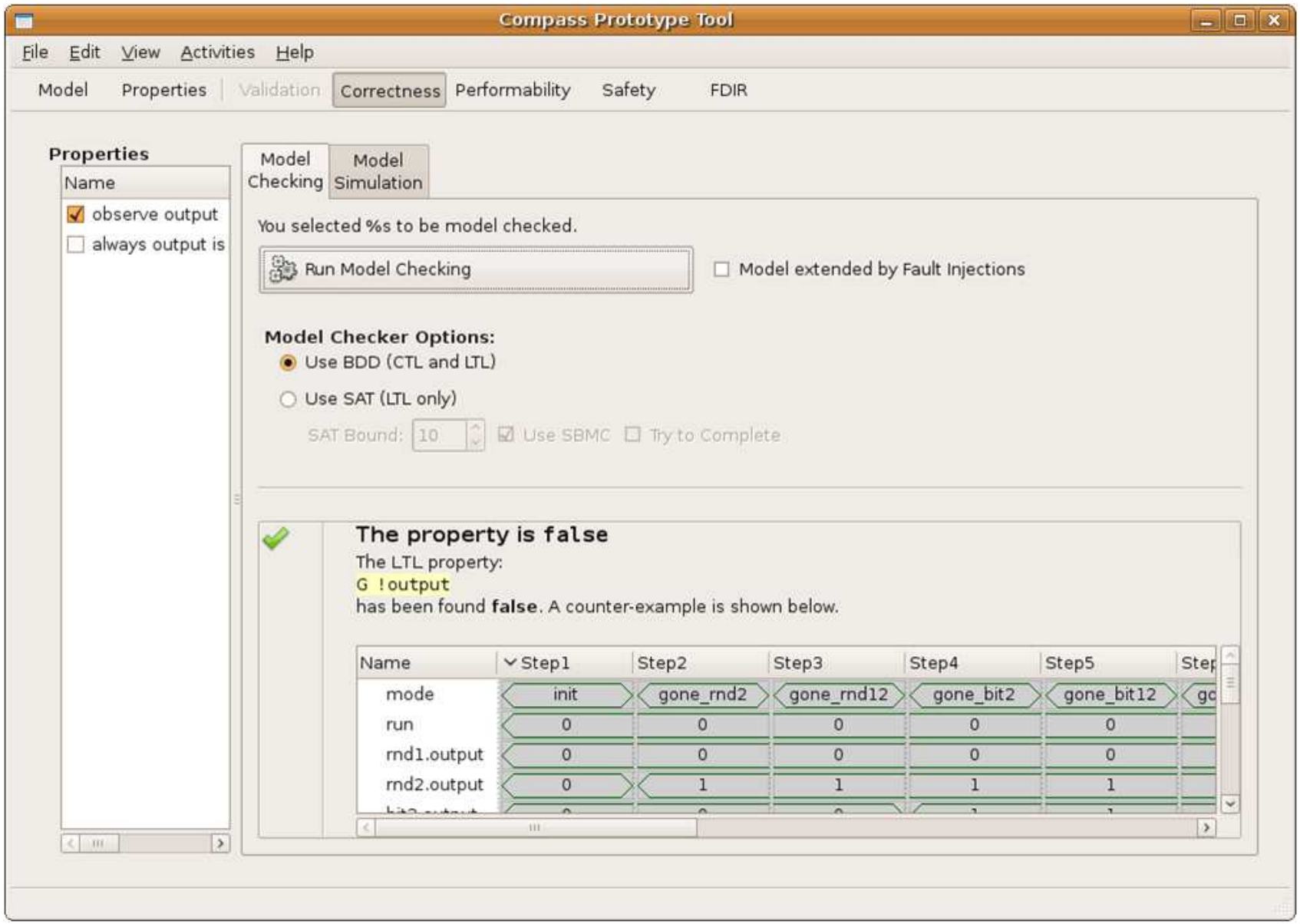
- Applied case studies from Europe's space-industry

COMPASS Toolset 2.0

Based on NuSMV and Markov Reward Model Checker



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Given an input $\mathcal{M}$ and a slicing criterion Φ, compute a $\mathcal{M}^{\Phi}_{sliced}$ such that the following holds:

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Today Property-driven slicing of system-level models.

Property-Driven Slicing of AADL

Given an AADL model $\mathcal{M}$ and a CTL*-property Φ

1. Extract the *data elements* and *modes* of direct interest.
2. Compute the closure of data elements and modes of indirect influence (next slide).
3. Generate $\mathcal{M}^{\Phi}_{sliced}$

Static Analysis for Determining Interesting Parts

$D := \{d \in \textit{Dat} \mid d \text{ occurs in } \Phi\}$;
$E := \emptyset$;
$M := \{m \in \textit{Mod} \mid m \text{ occurs in } \Phi\}$;
} Initialization based on the property Φ.

repeat

until nothing changes;

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for all $m \xrightarrow{e,g,f} m' \in \textit{Trn}$ with $\exists d \in D : f$ updates d
or $\exists d \in D : d$ inactive in m but active in m'
or $e \in E$ **do**
$M := M \cup \{m\}$;

} Add source modes of transitions that affect interesting data elements.

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for all $d := a \in \textit{Flw}$ with $d \in D$ **do**
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} Add data elements and modes of interesting flows.

until nothing changes;

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for all $e \rightsquigarrow e' \in \textit{Con}$ with $e \in E$ or $e' \in E$ **do**
$E := E \cup \{e, e'\}$;
$M := M \cup \{m \in \textit{Mod} \mid e \rightsquigarrow e' \text{ active in } m\}$;
} Add events and modes of interesting event ports.

until nothing changes;

Example: Adding Random Integers

```
system IntAdder
 features
  x: in data port int;
  y: in data port int;
  sum: out data port int;
end IntAdder;

system implementation
  IntAdder.Impl
 flows
  sum := x + y;
end IntAdder.Impl;
```

```
bus Bus
end Bus;

bus implementation
  Bus.Impl
end Bus.Impl;
```

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bus Bus
end Bus;

bus implementation
  Bus.Impl
end Bus.Impl;
```

```
system IntAdderFrame
end IntAdderFrame;

system implementation IntAdderFrame.Impl
 subcomponents
  random1: system RandomIntValue.Impl
           accesses aBus;
  random2: system RandomIntValue.Impl
           accesses aBus;
  adder: system IntAdder.Impl
         accesses aBus;
  aBus: bus Bus.Impl;
 connections
  data port random1.value -> adder.x;
  data port random2.value -> adder.y;
 modes
  choose1: activation mode;
  choose2: mode;
 transitions
  choose1 -[random1.update]-> choose2;
  choose2 -[random2.update]-> choose1;
end IntAdderFrame.Impl;
```

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$$\mathcal{M} \models \Box\,(0 \leq random1.value \leq 30 \wedge 0 \leq random2.value \leq 30)$$

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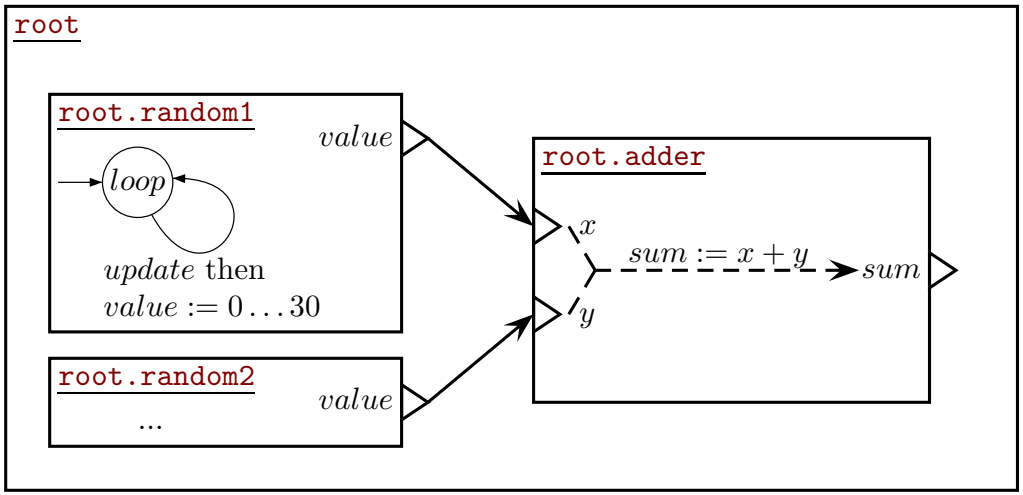

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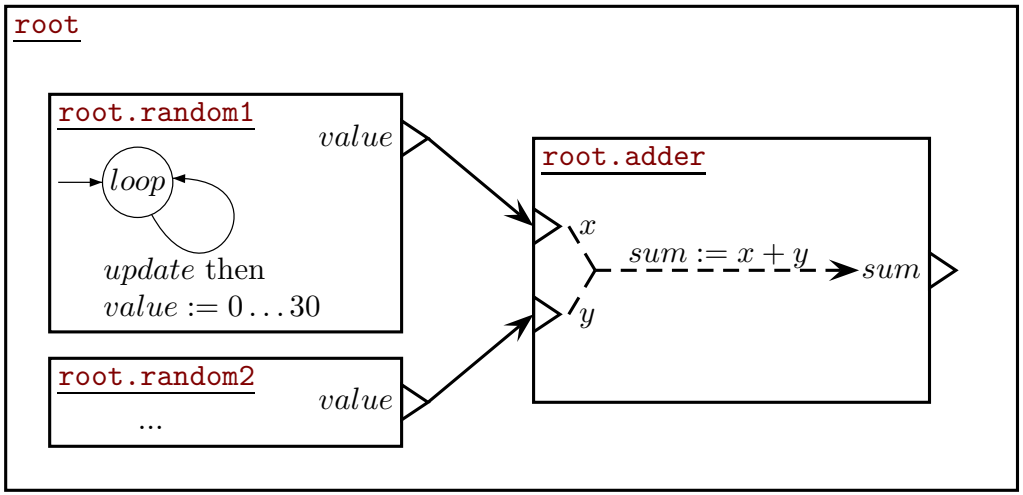

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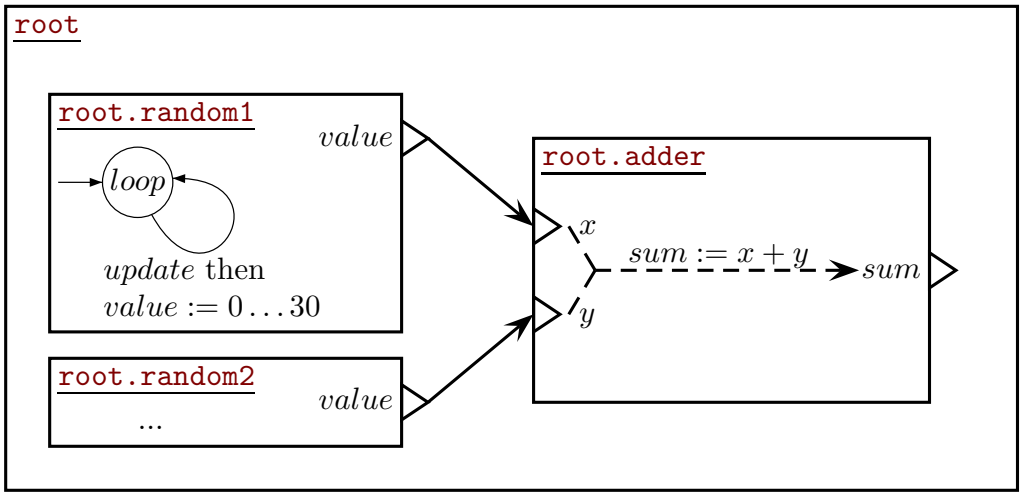

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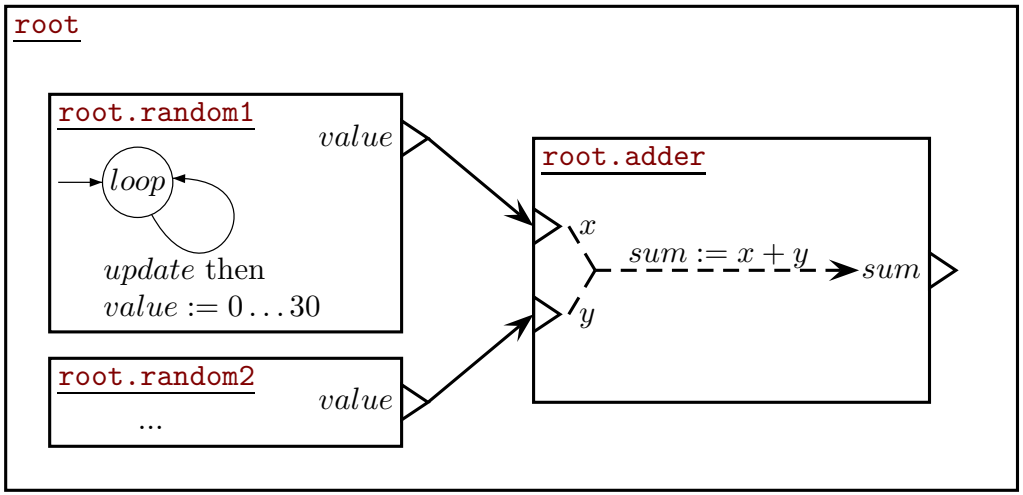

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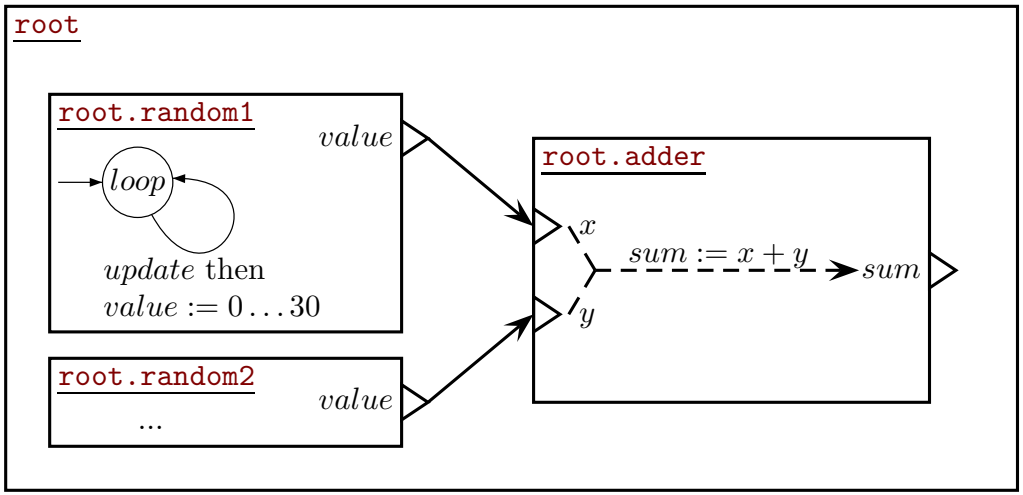

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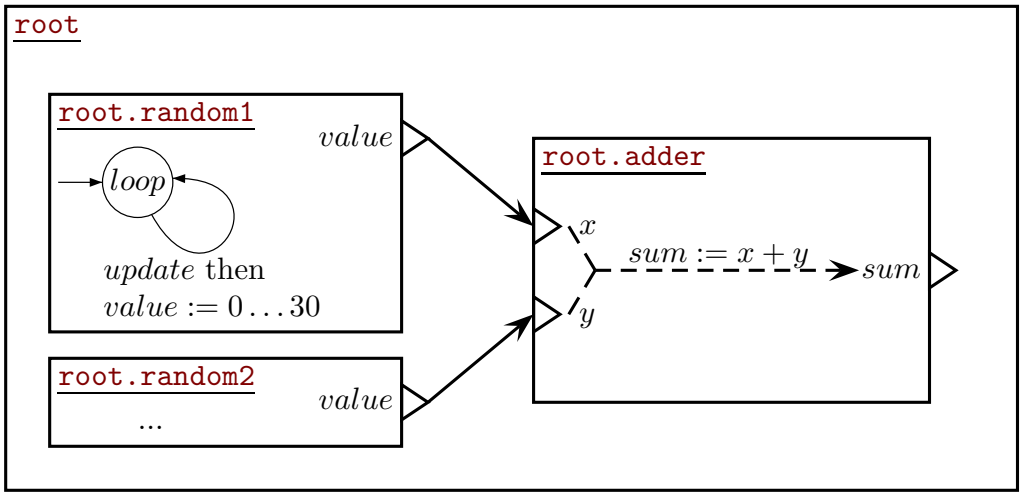

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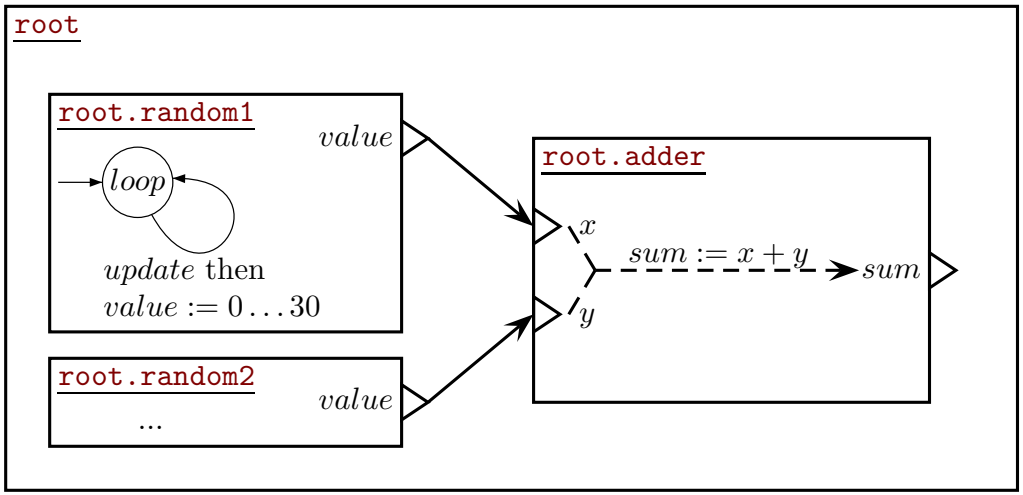

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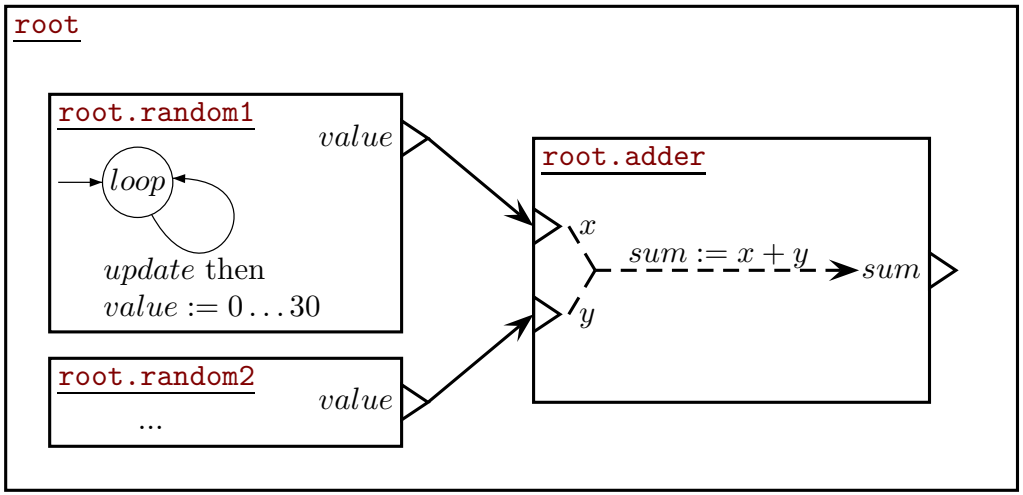

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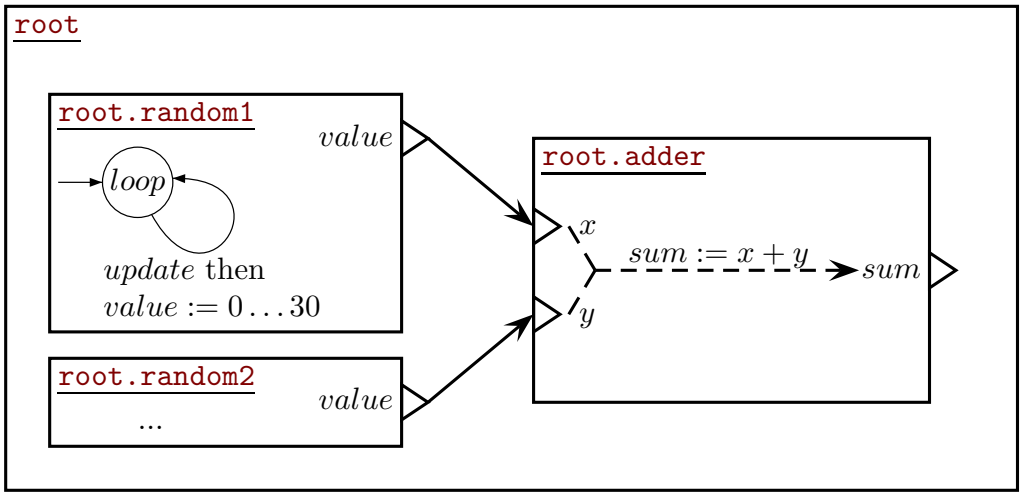

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Benchmarks Sliced versus Unsliced using AADL to Promela Translator[1]

Specification	Mem/State (bytes)	#States	Memory (MBs)	Time (seconds)
Unsliced	136	1,676,026	272	6.0 - 7.3
Sliced for Φ_1	116	1,437,691	211	5.4
Sliced for Φ_2	84	553,553	84	1.4
Sliced for Φ_3	76	9,379	33	0.1

$$\Phi_1 \equiv \Box\,(0 \leq adder.sum \leq 60)$$

$$\Phi_2 \equiv \Box\,(0 \leq random1.value \leq 30 \wedge 0 \leq random2.value \leq 30)$$

$$\Phi_3 \equiv \Box\,(0 \leq random1.value \leq 30)$$

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More benchmarks with similar results: negator, redundant battery system, wind turbine, satellite's thermal regulator!

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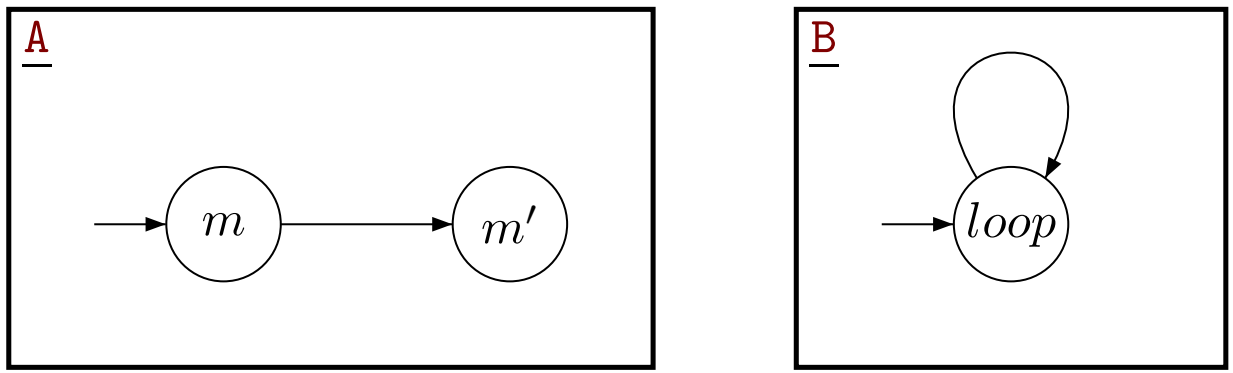
Remarks

- Preserving divergence characteristics.
  For example, $M \not\models \Diamond m'$ for the model below but when component B is sliced away, $M \models \Diamond m'$.



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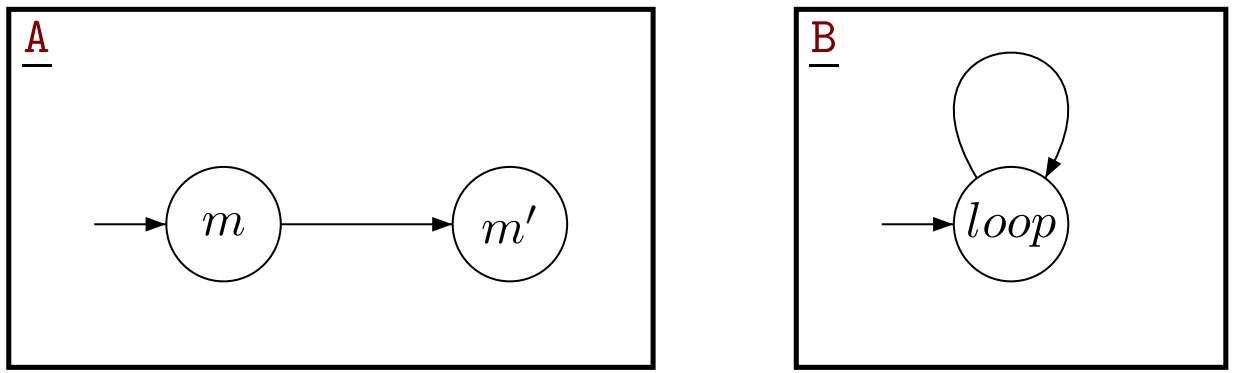

  Solution: static cycle detection and include all components with possible divergence behaviour.
- Refinement by distinguishing component-local and global data elements.

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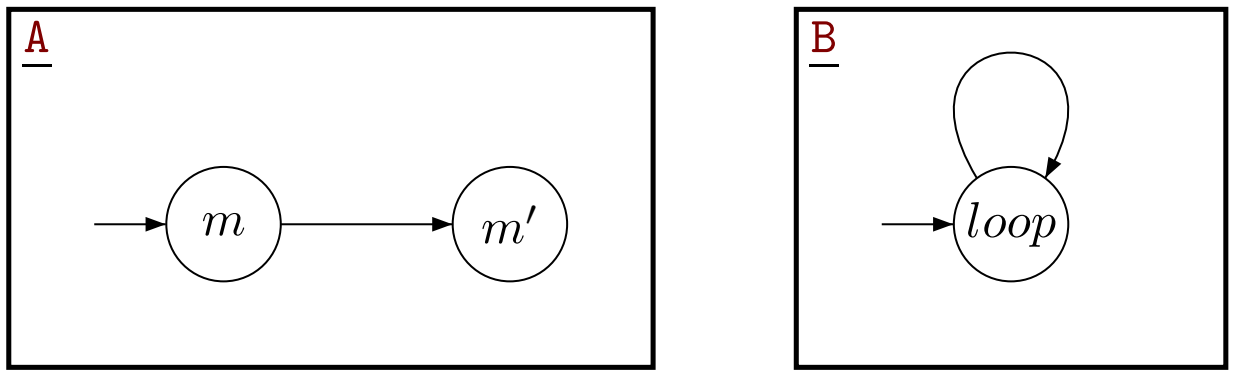

  Solution: static cycle detection and include all components with possible divergence behaviour.
- Refinement by distinguishing component-local and global data elements.
- *Initial* work-progress on preserving hybrid behaviour.

Summary

We developed a property-driven slicing algorithm for AADL that preserves CTL*. Benchmarks show an expected significant reduction in model checking time and memory on the sliced models.

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References:

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