Using Standard AADL for COMPASS

Thomas Noll (`noll@cs.rwth-aachen.de`)

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Software Modeling and Verification Chair
RWTH AACHEN UNIVERSITY

Overview

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SLIM Language Updates

COMPASS Development Roadmap

Fault Injections

Parametric Error Models

Timed Failure Propagation Graphs

Outline

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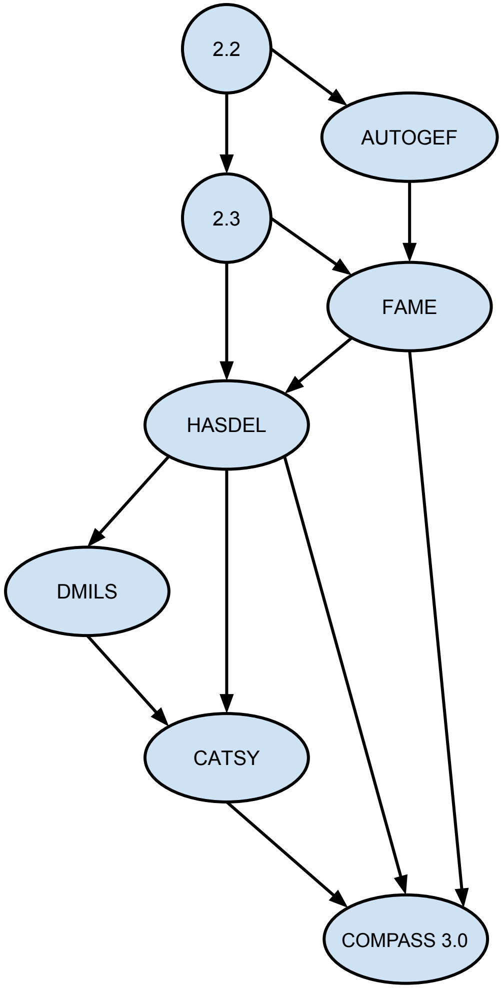
COMPASS Sub-projects and Extensions

On RWTH side:

1. COMPASS started in 2008
2. HASDEL in 2013
3. D-MILS in 2013
4. CATSY in 2015

Other projects (FBK):

1. AUTOGEF (2011)
2. FAME (2012)



Introduction

Issues

Many previous projects and many ideas. This leads to some issues:

- Legacy code
- Outdated tools
- As many code repositories as there are projects

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To address this, there is now: COMPASS 3

COMPASS 3

Project goals:

- Update SLIM language
- Update tools
- Improve examples and tutorials
- Set up development roadmap (also for ESA)

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Caveat: Properties Everywhere

SLIM properties: formalization of requirements as component annotations

```
system Simple
 features
  input: in event port;
  output: out event port;
  {OCRA: CONTRACT myContract
   assume:  in the future {input};
   guarantee:  always ({input} implies in the future {output});}
end Simple;
```

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end Simple;
```

AADL properties: generic mechanism for providing information about elements

```
process implementation MyProcess.Impl
 subcomponents
  t: thread MyThread.Impl;
 properties
  Example::Stack_Size => 2 KB;
end MyProcess.Impl;
```

SLIM Language Changes

Main goal of SLIM update: re-integration with AADL V2 [V3]

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Multiple benefits:

- Easier to get industry acceptance: AADL is a known language
- Possible to use existing AADL tooling (e.g., no editor specifically for SLIM)
  - OSATE2 development environment can be used for AADL V2

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Approach: use AADL properties mechanism to represent SLIM-specific features

`SLIMdatatypes`: embedding of SLIM data types in AADL

`SLIMpropset`: AADL properties for specifying special-purpose attributes of architectural elements such as ports

`CSSP`: AADL properties for specifying SLIM properties in *Catalogue of System and Software Properties* (cf. Harold's presentation on CATSY project)

SLIM Data Types

SLIM predefines a few basic data types:

- `bool`
- `int`
- `real`
- `enum`
- `clock`
- `continuous`

AADL Data Types

AADL has a data type system that allows the definition of (custom) data types. For example:

Data type package

```
package SLIMdatatypes
  public
  data bool
  end bool;
  data int
  end int;
  data real
  end real;
  ...
end SLIMdatatypes;
```

Also useful for (nested) data types defined by the user.

SLIM Language Updates

AADL Properties for SLIM Attributes

Examples of port attributes:

`Alarm`: port is an alarm for FDIR analysis

`Blocking`: for blocking communication if incoming event (data) port not enabled

`Default`: for defining default values of data elements

`Observable`: for indicating observable parameters (FDIR analysis)

SLIM attributes as AADL properties

```
system sys
 features
  input: in event port
   blocking;
  output: out data port
   int default 1;
end sys;
```

$\rightsquigarrow$

```
system sys
 features
  input: in event port
   {Blocking = true;};
  output: out data port int
   {Default => "1";};
end sys;
```

SLIM Language Updates

Storing Contracts

SLIM contracts as AADL properties

```
system simple
 features input: in event port; output: out event port;
  {OCRA: CONTRACT myContract
   assume:  in the future {input};
   guarantee:  always ({input} implies in the future {output});}
end simple;
```

$\rightsquigarrow$

```
system simple
 features input: in event port; output: out event port;
 properties
  Contracts => [
   {Name => "myContract";
    Assumption => "in the future input";
    Guarantee =>
     "always ({input} implies in the future {output})";}];
end simple;
```

SLIM Language Updates

AADL Property Set for SLIM

SLIM properties

```
property set SLIMpropset is
  Blocking: aadlboolean => true
    applies to (event port, event data port);
  TimeUnit: ClockTimeUnit applies to (data);
  ClockTimeUnit: type enumeration (Milliseconds, Seconds, ...);
  Contracts: list of SLIMpropset::Contract
    applies to (system, process, ...);
  Contract: type record (
    Name: aadlstring;
    Assumption: aadlstring;
    Guarantee: aadlstring;);
  ContractRefinement: type record (
    Contract: aadlstring;
    SubContracts: list of aadlstring;);
  ContractRefinements: list of SLIMpropset::ContractRefinement
   applies to (system, process, ...);
  ...
end SLIMpropset;
```

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COMPASS Development Roadmap

- Deliverable of COMPASS 3 project
- To identify future steps of COMPASS and prepare corresponding development and release plan

COMPASS Development Roadmap

- Deliverable of COMPASS 3 project
- To identify future steps of COMPASS and prepare corresponding development and release plan
- Strategic aims:
  - extend usability and applicability of toolset
  - identify and remove limitations that prevent “market” penetration and industrial usage

  $\Rightarrow$ reach higher levels of technology readiness
- Derived goals:
  - improving system development process
  - advancing COMPASS technology, mainly w.r.t. error modeling and analysis

COMPASS Development Roadmap

Improving the System Development Process

- Main concern: integration of COMPASS modeling, analysis, and validation activities with design and implementation steps supported by other (AADL) tools (TASTE, Simulink, ...)
- Requires methods for checking conformance between hardware/software implementation and AADL model: model-based testing
  - steer automated generation of test cases by AADL model

COMPASS Development Roadmap

Advancing Error Modeling and Analysis

- More expressive fault injections
- Parametric error models
  - parameter synthesis
  - model repair
- Timed failure propagation graphs
- Formal validation of requirement specifications
- Contract-based design
- More efficient analysis of dynamic fault trees

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Advancing Error Modeling and Analysis

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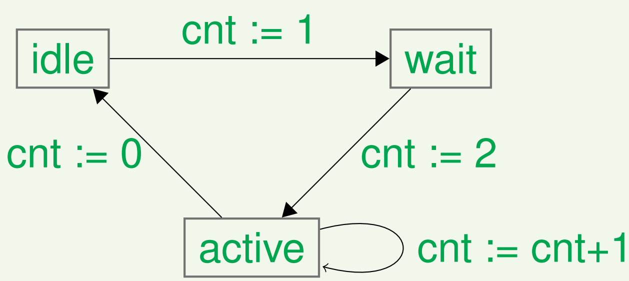
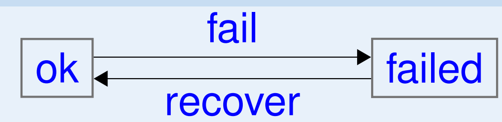
SLIM Error Modeling

Nominal behavior



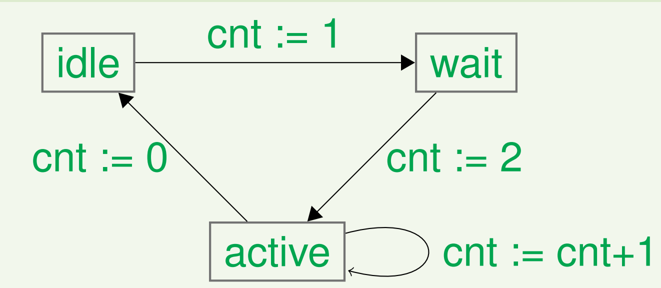
Error behaviour



Fault Injections

SLIM Error Modeling

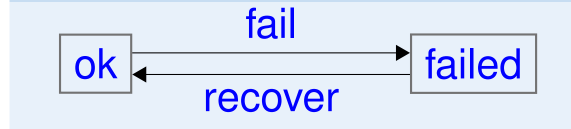
Nominal behavior



Fault injection

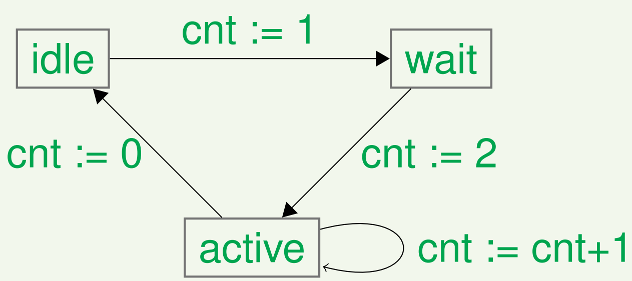
failed: cnt := -1

Error behaviour



SLIM Error Modeling

Nominal behavior



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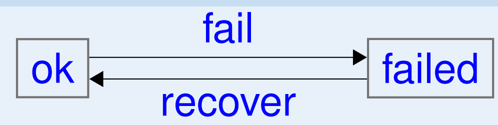
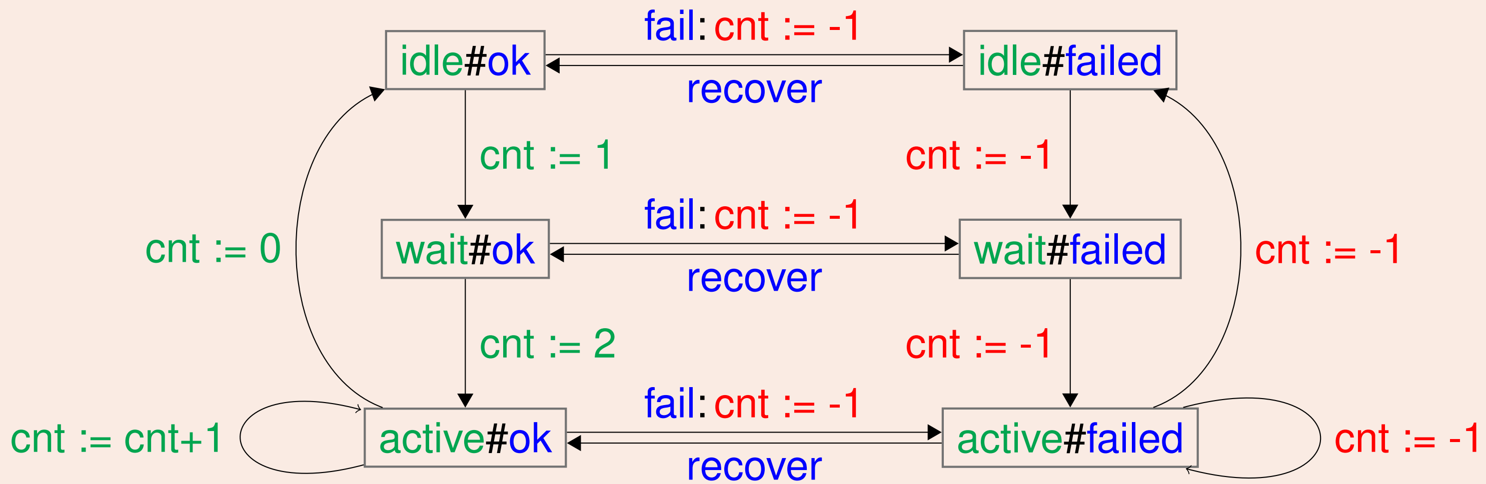


Extended model



Fault Injections

Current Fault Injection Mechanisms

`SLIMpropset` properties for fault injection

```
-- Modify nominal data value while in error state
FaultEffect: type record (
  State: aadlstring;
  Target: reference(data port, data);
  Effect: SlimExpr;);

-- Restrict possible modes while in error state
ForcedMode: type record (
  State: aadlstring;
  Modes: list of reference(mode););

-- Disable event ports while in error state
Inhibit: type record (
  State: aadlstring;
  Ports: list of reference(event port, event data port););
```

Possible Enhancements of Fault Injection

Possible enhancements to increase expressiveness and usability

- Transient fault effects
  - only when *entering* state s, the assignment $d := e$ is performed
- Error-triggered nominal transitions
  - error transition $s \rightarrow s'$ causes mode transition $m \rightarrow m'$

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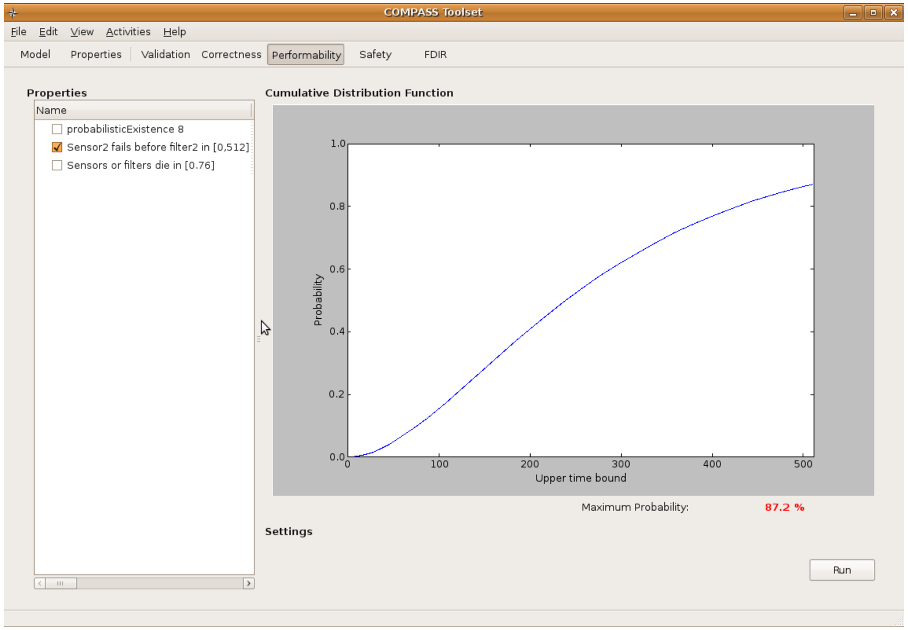
Parametric Error Models

- Performability evaluation: determine likelihood of system failure within given deadline



Parametric Error Models

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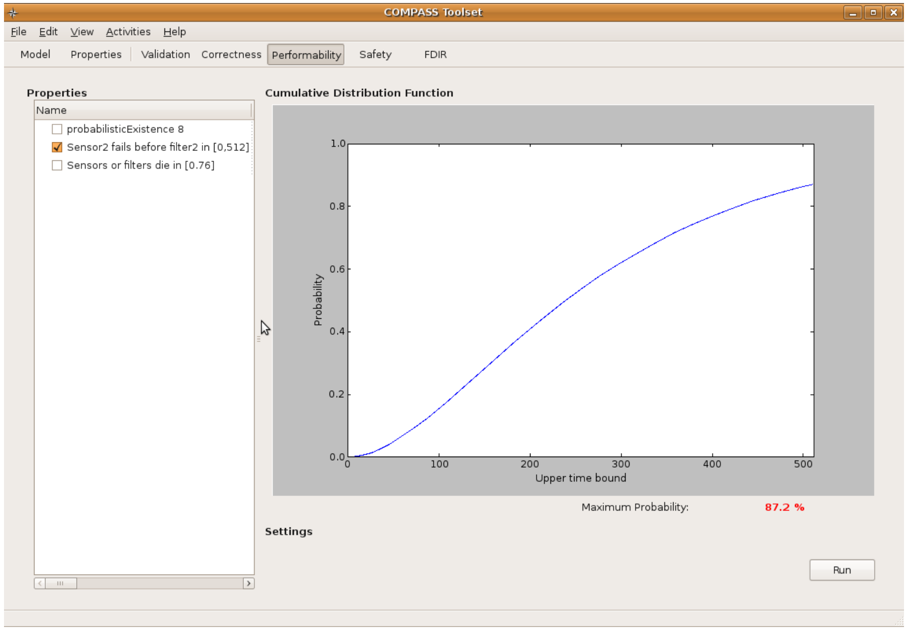


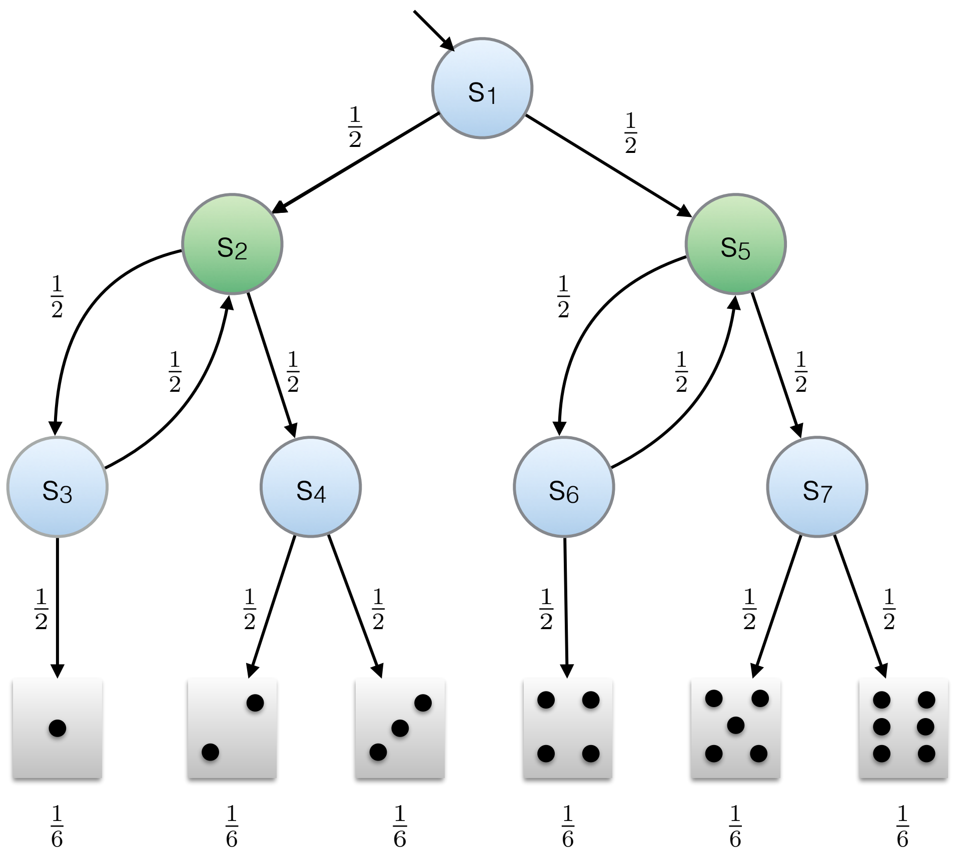
- But: probabilities of basic faults often not (exactly) known

$\Longrightarrow$ Parametric error models

- automatically compute maximal tolerable fault probabilities

Parametric Error Models

Knuth-Yao Die



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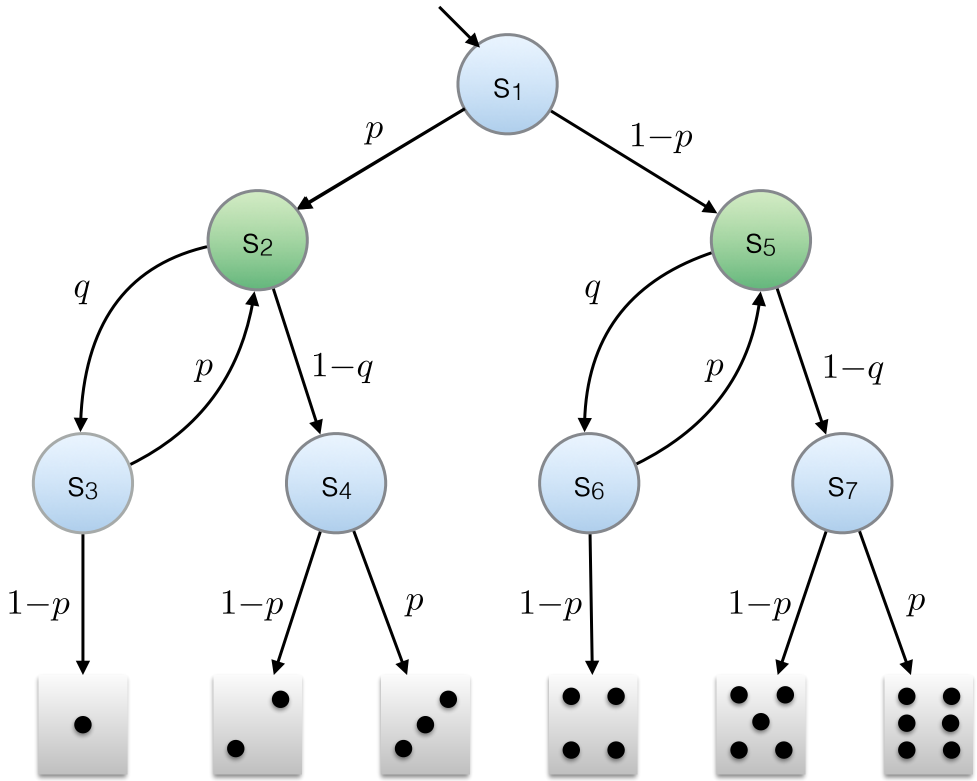

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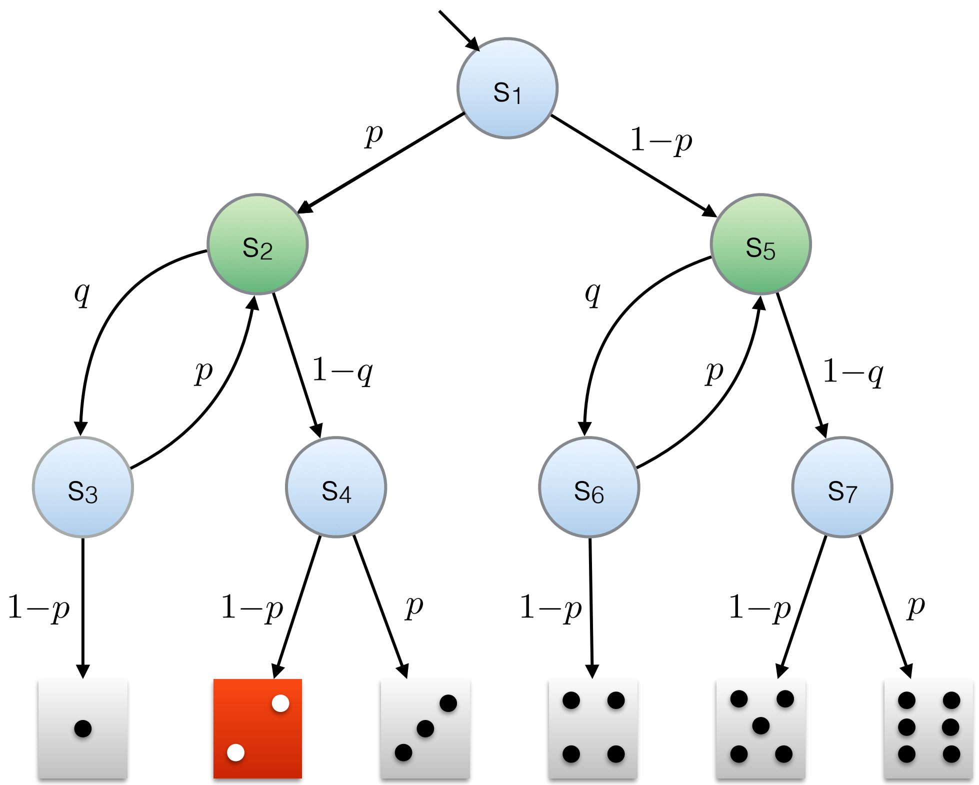
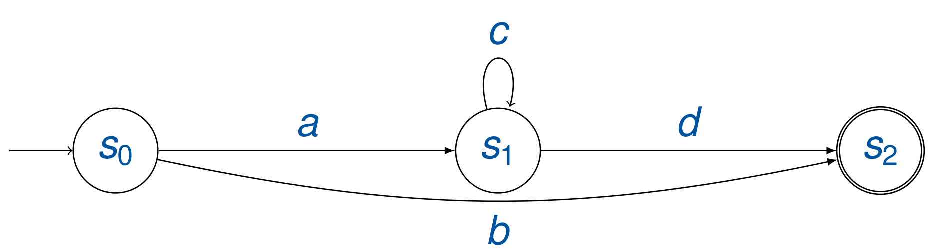


PARAMETRIC REACHABILITY PROBABILITY

State elimination

To calculate the regular expression which represents $\mathcal{L}(s_0, \mathcal{A})$ state elimination is used



$\Rightarrow$ Eliminate state s_1:

$\Rightarrow$ We receive the accepted Language $\mathcal{L}(s_0, \mathcal{A}) = a.c^{\star}.d \mid b$

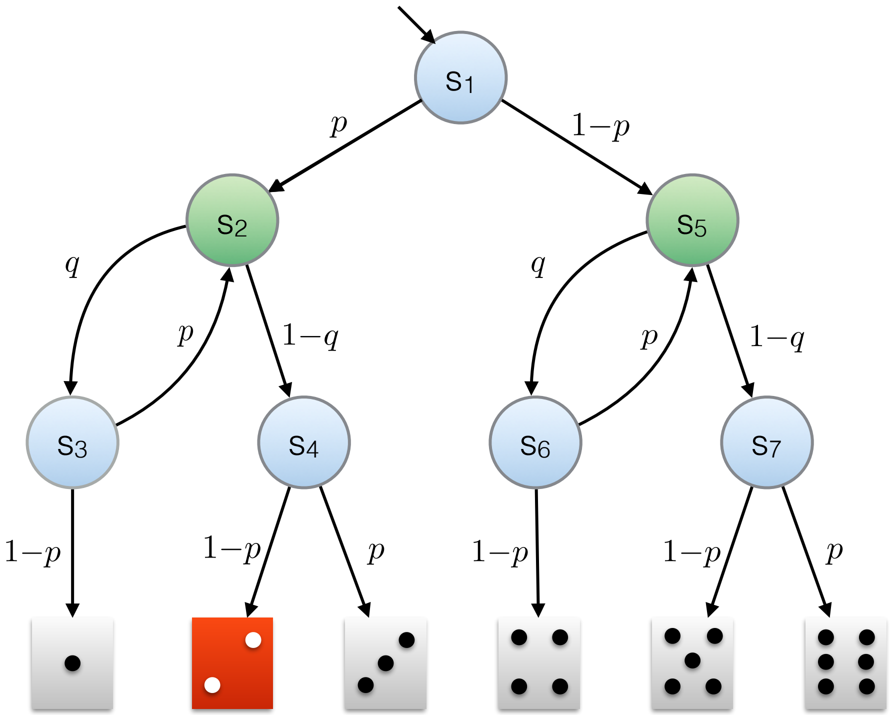
From Languages to Probabilities

Probabilistic interpretation of regular operations

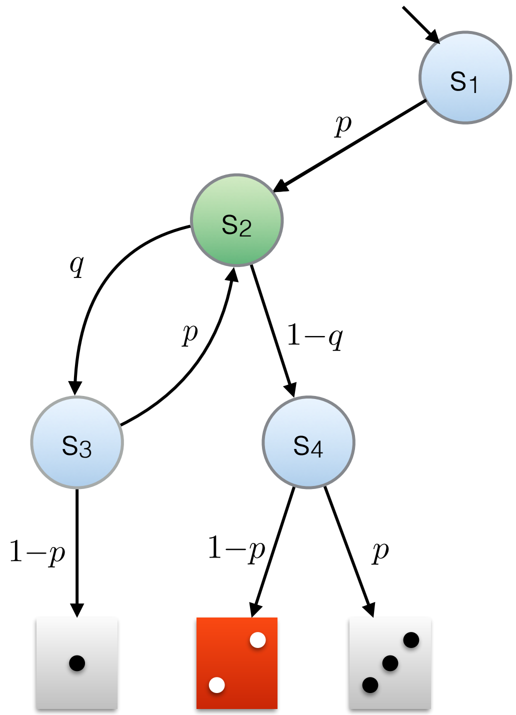
- Concatenation . corresponds to multiplication
- Union | corresponds to addition
- Kleene star $x^* = \varepsilon \mid x \mid xx \mid \ldots$ corresponds to limit of geometric series $\sum_{k\in\mathbb{N}} x^k = \frac{1}{1-x}$

Parametric Error Models

State Elimination



State Elimination



Parametric Error Models

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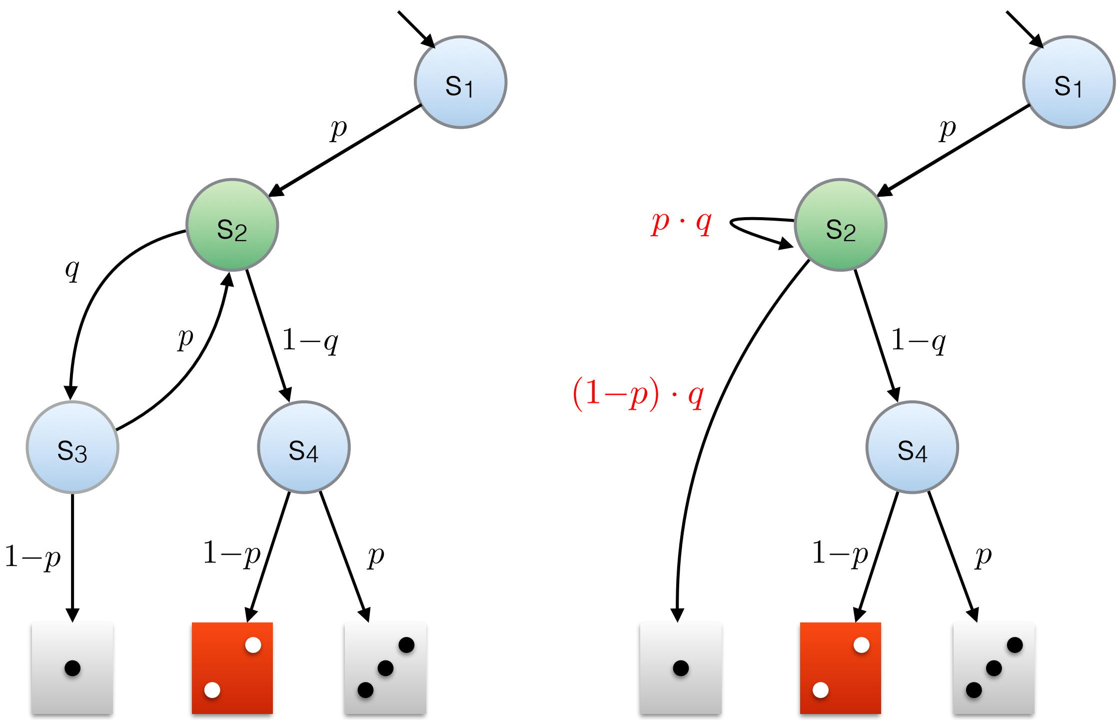

Parametric Error Models

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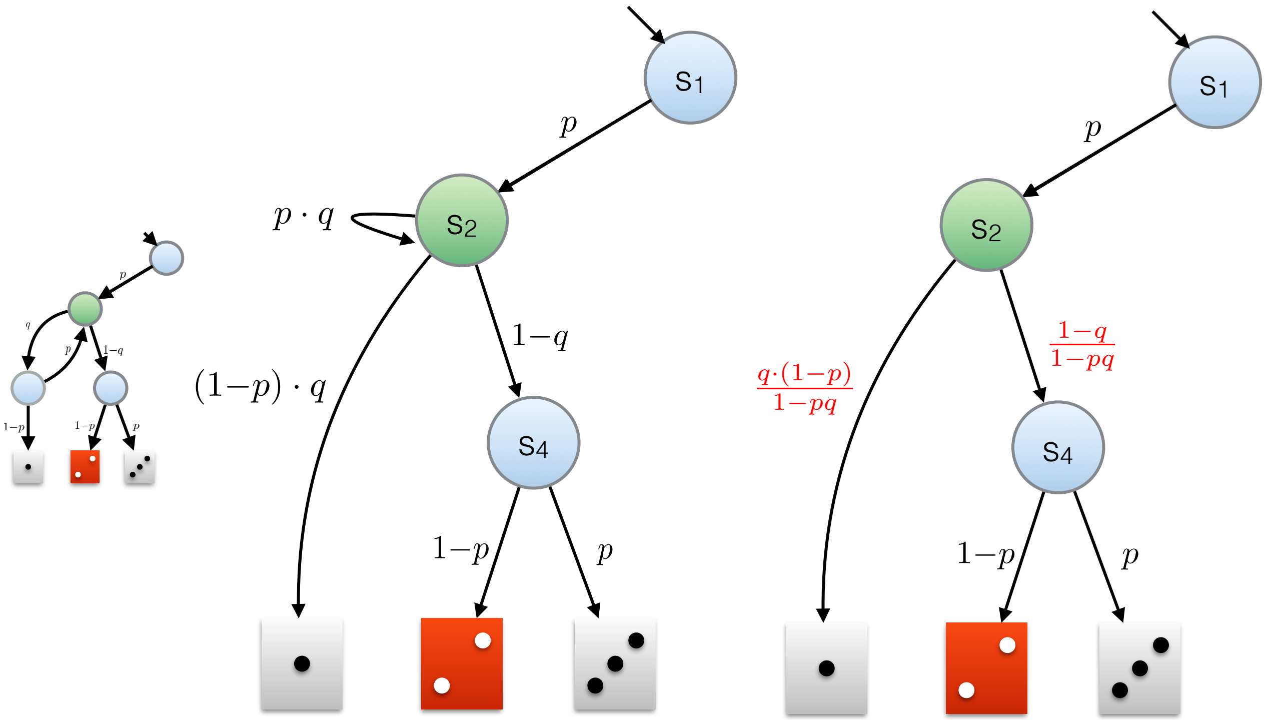

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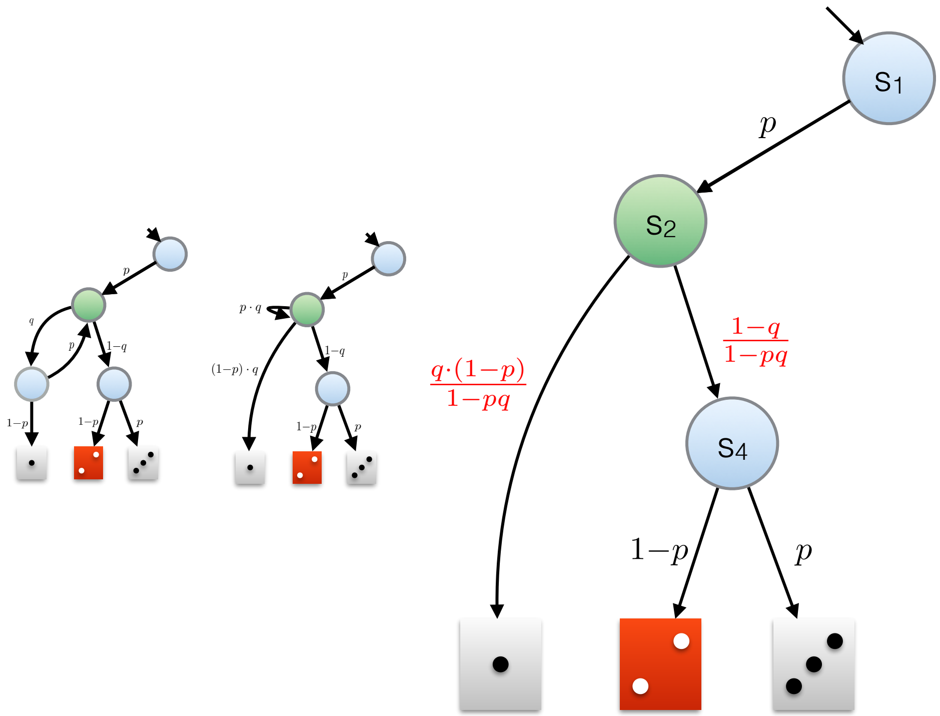

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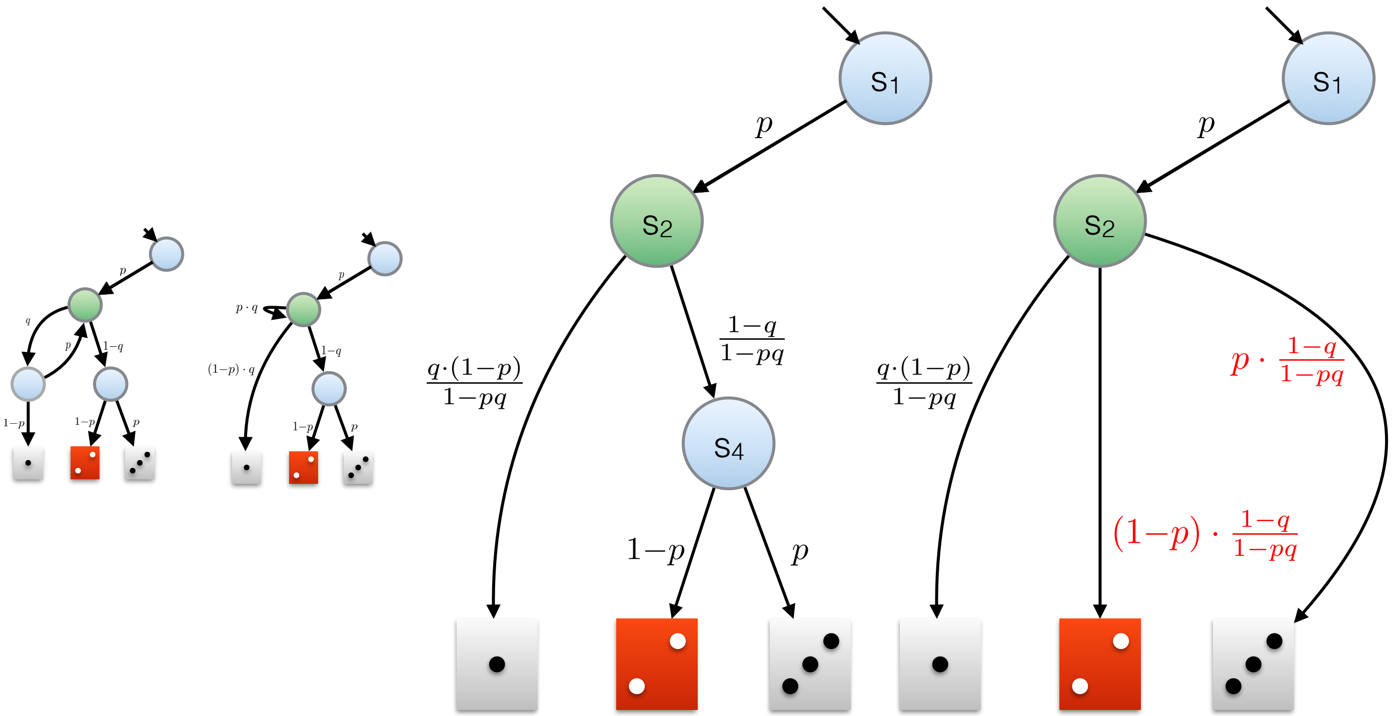
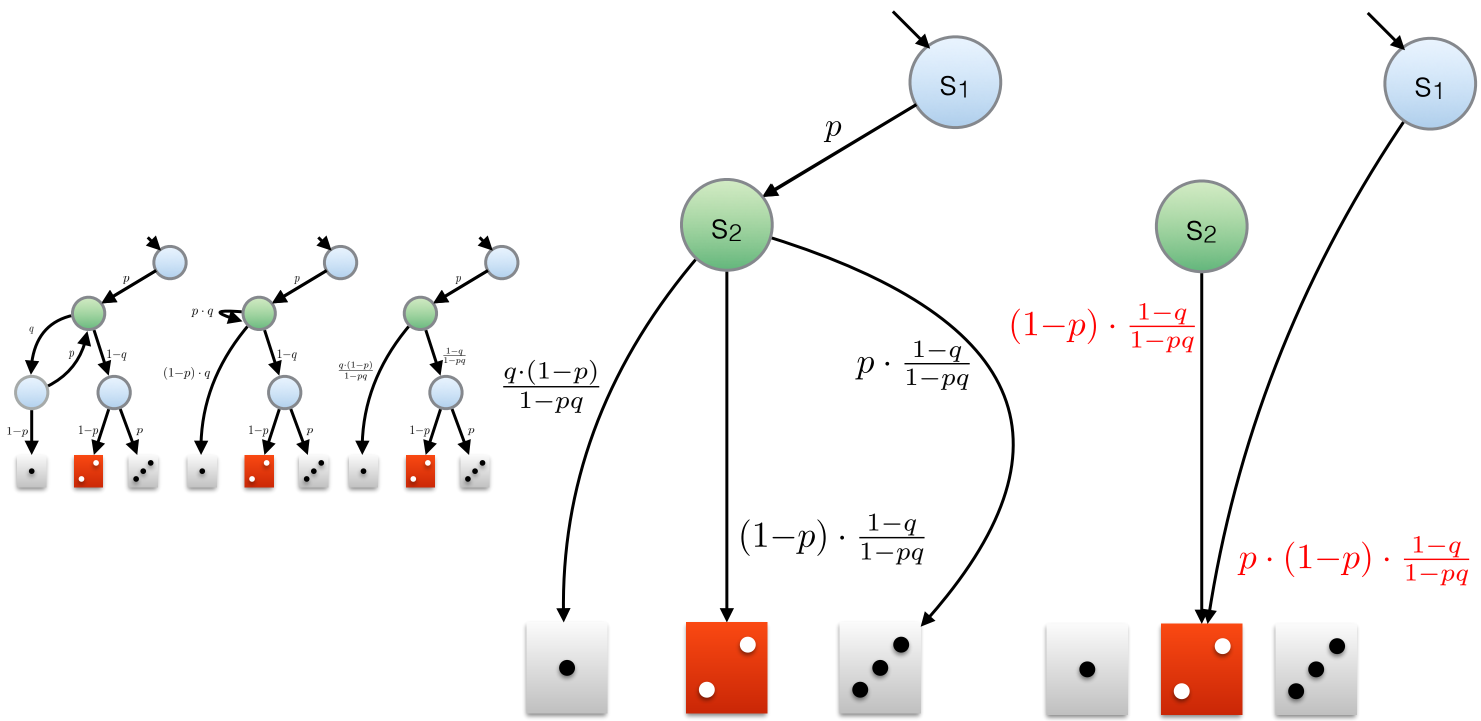
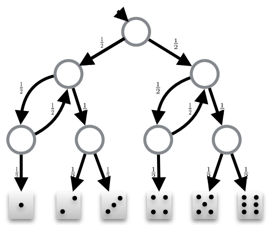
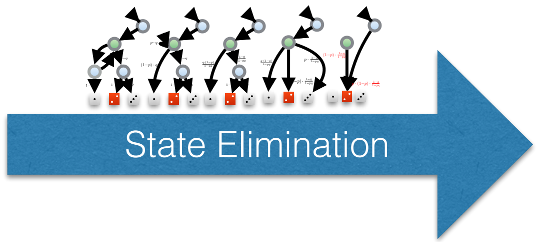


State Elimination



Result of State Elimination





?

Rational function over the parameters

Numerically instable

large

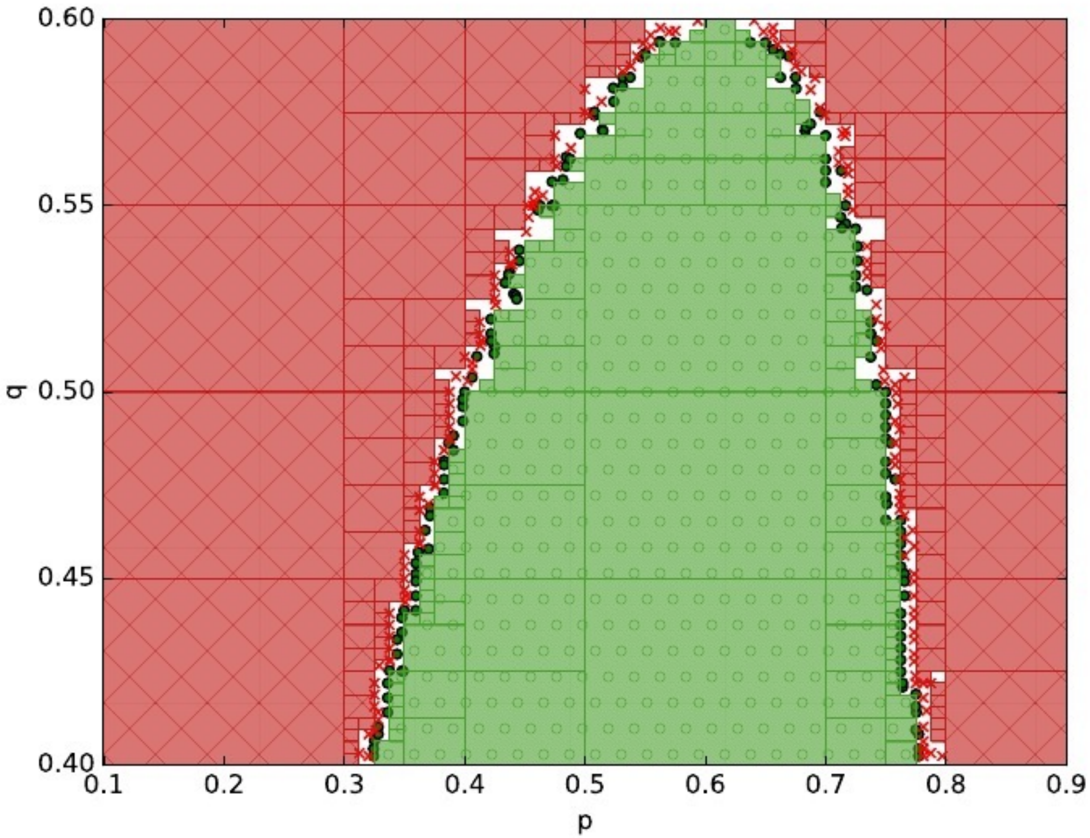
Used by:

[Bartocci et al., 2013]

[Calinescu et al., 2016]

[Rosenblum et al., 2016]

Parameter Space Partitioning

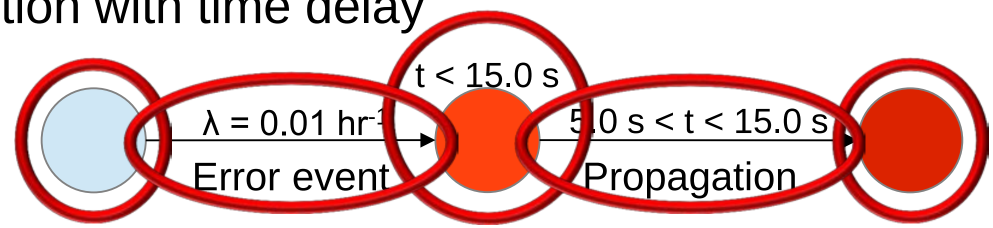


Outline

SLIM: Timed Failure models

An example: modelling error propagation

- First transition with probabilistic rate
- Next transition with time delay




```
error model SubError
features
  err_prop : out error propagation;
end SubError;

error model implementation SubError.Impl
events
  err_evt : error event occurrence poisson 0.01 per hour;
states
  e_nominal : initial state;
  e_triggered : error state urgent in 15 sec;
  e_propagated : error state;
transitions
  e_nominal -[err_evt]-> e_triggered;
  e_triggered -[err_prop between 5 sec and 15 sec]-> e_propagated;
end SubError.Impl;
```

Timed failure propagation graphs (TFPG)