Formal Methods for SPIDER

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Introduction

Safety-Critical Systems
   Overview
   SPIDER: A Fault-Tolerant Communications Bus

Formal Methods
   What are Formal Methods and Why Use Them?
   Tools of the Trade
   Formal Methods for SPIDER

Conclusion
What is a Safety-Critical System?

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- Aircraft
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[Images of an aircraft and a car]
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- Medical Devices
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- Odds of being hit by lightning in a year: 1 in 240,000 ($1/2.4 \times 10^{-5}/\text{year}$).
- Odds of dying in a car wreck per trip: 1 in 4 million ($1/4 \times 10^{-6}/\text{trip}$).
Current Trends in Safety-Critical Embedded Systems
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Every day, our lives are in the hands of computers.
SPIDER: What Is It?

**Scalable Processor-Independent Design for Enhanced Reliability**

A means to safely integrate embedded systems and partition faults.
The Need for SPIDER

Integrating interdependent applications of differing criticality in extreme safety-critical environments.
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For use in

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- Highly-automated environments (e.g., unpiloted air vehicles).
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For use in

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- Highly-automated environments (e.g., unpiloted air vehicles).
- Highly-integrated environments (e.g., tomorrow’s commercial aircraft).
Architecture
ROBUS Protocols

Highly fault-tolerant protocols implemented for

- Initial Clock Synchronization
- Clock Resynchronization
- Distributed Diagnosis
- Interactive Consistency
- Reintegration
What are Formal Methods?

*Formal methods* is a field in which formal mathematical techniques are applied to ensure the correctness of digital systems.

\[
\begin{align*}
\frac{\varepsilon_3}{\varepsilon_1} &= \frac{A'}{A^2} \beta^2 \\
\varepsilon_1 &= \left(\frac{A}{A+1}\right)^2 E_1 \\
\mu_3 &= \mu \\
\frac{\varepsilon_4}{\varepsilon_1} &= \frac{A'}{A+1 - A'} \frac{\varepsilon_3}{\varepsilon_1} \\
\mu_4 &= \mu
\end{align*}
\]
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Design assurance via testing is infeasible for safety-critical systems.
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  - The complexity of specifying digital systems.
- Little feedback provided for why a proof fails (which is a common occurrence).
In Other Words...

What it is like to use a theorem prover.
Model-Checking

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- Model-checking languages are constrained.
(Interactive and Automated) Compilation

Interpreters and compilers are so ubiquitous that they are rarely thought of as formal methods, but they are.
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- An interactive compiler allows the user to guide the compilation (e.g., optimizations for a specific architecture).
- The design space of compilation is more restrictive than theorem-proving.
Which methods?

All three methods are used for SPIDER. The specific tools used are

- PVS, a mechanical theorem-prover developed at SRI.
- SAL, a (family of) model-checkers developed at SRI.
- SMART, a model-checker developed at William & Mary.
- DRS, an interactive hardware compiler developed at Derivation Systems, Inc. (based on research by Steve Johnson, Indiana Univ., Bloomington).
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Tools of the Trade

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Formal Methods for SPIDER

SAL Screenshot
Formal Methods for SPIDER

SMART Screenshot

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Formal Methods for SPIDER
What are Formal Methods and Why Use Them?

Tools of the Trade

Formal Methods for SPIDER
How are Formal Methods Applied to the Design of SPIDER?

- Theorem-Proving is used to specify and verify fault-tolerant protocols.
- Model-checking is used to specify and verify fault-tolerant protocols.
- Interactive compilation is used to derive hardware for individual system nodes.
Ongoing Work in Formal Methods

- A fault-tolerance library for theorem-proving.
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- A fault-tolerance library for theorem-proving.
- Better abstractions for theorem-proving/model-checking.
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- Technology transfer to government and industry.
Summary

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- Formal methods can greatly facilitate the design and validation of safety-critical systems.
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- Formal methods can greatly facilitate the design and validation of safety-critical systems.
- Formal methods are not a panacea, but they increase the assurance of correct design.
Resources

**SPIDER Project**

http://shemesh.larc.nasa.gov/fm/spider/

*Google*: formal methods spider

**NASA Langley Research Center Formal Methods Group**

http://shemesh.larc.nasa.gov/fm/

*Google*: nasa formal methods
Resources (Cont.)

Formal Methods Virtual Library

http://www.afm.sbu.ac.uk/
Google: formal methods

Formal Methods and the Certification of Critical Systems
by John Rushby

http://www.csl.sri.com/papers/csl-93-7/
Google: rushby certification formal methods
## Formal Methods Tool Websites

<table>
<thead>
<tr>
<th>Tool</th>
<th>Website</th>
<th>Google Query</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMART</td>
<td><a href="http://www.cs.wm.edu/~ciardo/SMART/">http://www.cs.wm.edu/~ciardo/SMART/</a></td>
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