A Ptolemy II Implementation of the TRANSCEND system for Model Based Fault Detection and Isolation in Continuous Dynamic Systems

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Outline

- Introduction: What, Why, and So What
- TRANSCEND: Framework for Model Based Fault Detection and Isolation
- Implementation in Ptolemy II
- Example: Multi-tank Fluid System
- Summary and plans for further work
Introduction

- **What**: Computational framework for Model Based FDI
- **Why**: Complex computational issues
  - Multiple concurrent tasks: signal processing, diagnosis algorithms, visualization
  - Online FDI subject to real-time requirements
- **So What**: Long term goal: integrate FDI as embedded system application for “smart physical systems”

Model Based Fault Detection and Isolation

- FDI with functional models
  - Exploit analytical redundancy in a system model
  - Require estimate of nominal behavior
  - Deviation from nominal behavior triggers FDI

- Many Approaches

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<tbody>
<tr>
<td>Quantitative</td>
<td>State/Parameter Estimation</td>
<td>Constraint analysis (AI)</td>
</tr>
<tr>
<td>Qualitative</td>
<td><strong>TRANSCEND</strong></td>
<td>Discrete Event Approaches</td>
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</tbody>
</table>
Model Based Fault Detection and Isolation (2)

- Arguments for the qualitative approach
  - Model accuracy (structural + parameter estimation)
  - Computational problems in numerical solution methods
    (e.g. convergence)

- Problems with traditional AI modeling approaches: under-constrained models lead to many spurious hypotheses

TRANSCEND: transient based diagnosis

- Abrupt faults in continuous dynamic systems
  - Abrupt faults introduce Transients
  - Fault isolation is based on transient analysis

- Description of transient dynamics:
  qualitative magnitude and derivative values (-,0,+)

- Incremental analysis of transient behavior

- Topological Models based on physical principles:
  graph representation provides direct parameter to measurement relations
**TRANSCEND: modeling for FDI**

\[
f = \frac{p}{R} \quad \dot{p} = \frac{1}{C}(f_{in} - f)
\]

**TRANSCEND: system architecture**

- Key properties
  - Robust methods for signal to symbol transformation
  - Hypothesis generation: graph algorithms
  - Hypothesis refinement: qualitative fault observers
Top level actor

- Input: read residual data from file in off-line use
- Output: display active hypotheses as formatted text

Signal-to-Symbol transformation

- Derivative estimates computed with FIR filters
- Transient state controls hypothesis refinement
Qualitative Fault Detection and Isolation

Intermezzo: Python - One page Summary

- Python Language Features:
  - Byte-Code Compiled/Interpreted
  - Interactive
  - Object Oriented
  - Dynamic Semantics
  - Supports Modules and Packages

- Rapid Application Development support through:
  - High level data structures and operations Python source looks like “executable pseudo code”
  - Strong embedding/extending capabilities
Actor with Embedded Python components

- How it works
  - Create Python class derived from \texttt{java.lang.object}
  - Compile to Java byte-code with \texttt{jythonc}
  - Instantiate class as if native Java object
  - Application loads \texttt{jpython} package:
    Java implementation of the Python Virtual Machine

- Cool: Prototype Java components with RAD tool
- Catch: Performance hit over native Java

EXAMPLE: FDI of a multi-tank fluid system
EXAMPLE: FDI of a multi-tank fluid system (2)

Output of the Fault Isolation Process for fault $C2$—

> step 0

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>f3</th>
<th>e7</th>
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<tbody>
<tr>
<td>$C2^-$</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>$C1^-$</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>$Rb2^+$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$R12^-$</td>
<td>0</td>
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<tr>
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> step 1

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Active Hypotheses:

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Summary and plans for further work

- Current implementation allowed us to make TRANSCEND suitable for stream based processing.
- Gaining insight in concurrency issues for Model Based FDI systems
- Future plans:
  - Integrate simulator for Bond Graph models (in progress):
  - Migrate towards discrete time dataflow
  - Construct online FDI system for the physical three-tank system testbed in our lab
Final Notes

Please visit the
Modeling and Analysis of Complex Systems group
online at:
http://macs.vuse.vanderbilt.edu

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