Accelerated Stress Testing and Reliability Conference

Accelerated Stress & Reliability Testing for Software and Cyber-Physical Systems

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Overview

• Introduction – to the domain and the problem
• Background and review of prior work
• Testing approaches
  – Virtual time testing
  – Quantity-based testing
  – Combined software / cyber-physical system testing
• Case study
• Discussion of enhancements
Introduction

• What is a cyber-physical system
  – Combines software and real world actuation / sensing

• What challenges does testing a cyber-physical system present?
  – How do you test both the hardware and software in an accelerated manner?
  – How do you guarantee reliability across testing assumptions?
• Rajkumar, et al. suggest that cyber-physical systems represent a new “computing revolution”
  – They combine:
    • hardware actuation
    • sensing
    • other capabilities
  – With software system:
    • decision making
    • data storage
    • other benefits
Background – Cyber-physical Systems

• Cyber-physical system examples, use in:
  – automotive and aerial transportation
  – power grids
  – Healthcare
  – scientific discovery
  – emergency response

• Basic cyber-physical systems are very common and they’re getting progressively ‘smarter’
Background – Testing Autonomy

- Cholewinski, et al. – use one system to validate another
- Billings, et al. – self play testing
- Wotawa, et al. – mutation of manually created test cases
- AdiSrikanth, et al. – autonomous creation of base test cases
What Exactly is the Problem?

- Long term operations
  - System must operate (potentially without human help or service) for an extended period of time
  - Hardware must work
  - Software must work
  - These mean different things ...
- How do you test physical component performance and software long-term operations concurrently?
Virtual Time Testing

- Approach for testing software
- Aims to simulate use over an extended period of time
- May make use of more robust hardware than the production system.
  - Its, thus, able to run more commands at a faster rate
- May compress operations on production hardware if there is lots of time between operations
Quantity Based Testing

• Approach for testing physical mechanisms
• Based on identifying duty cycle of piece of equipment / mechanical structure / etc.
• Test the number of required actuations / stress applications / etc. over lifetime (with margin for error)
• Consider other factors (such as deterioration over time, etc.)
Combining the Two Approaches

- Even with a combined technique, one cannot expect to fully rapidly test a cyber-physical system.
- Increasing testing speed limits the amount of ‘real world’ operating conditions the hardware-software system is exposed to.
- The combined approach provides matching simulated input to both hardware and software components simultaneously.
Combining the Two Approaches (cont.)

- Testing scenarios must be developed, based on functional and non-functional requirements
  - Scenarios must electronically and physically stimulate and cause actuation of the cyber-physical system
- Complex intersections of numerous factors must be considered to determine if the testing plan has flaws or bad assumptions
- Requires synchronization between hardware and software simulation units
Case Study: Long Duration Space Mission

• Scenario: long duration space mission
  – Typical of planetary science missions
  – Missions of this type have been performed previously
  – Historically, they have not been as autonomous as future missions will be

• It will evaluate efficacy, demonstrate solution gaps
Case Study – Testing Plan

• Requirements
  – System will run continuously for years
  – Continuously collecting data, some changes decision making
  – No direct human access for maintenance or configuration changes

• Testing plan
  – Unit (hardware, software subsystems) testing
  – Integration testing
  – Accelerated hardware (quantity) / software (virtual time) testing
  – Custom designed engine to simulate providing data, physical environment
    • Test to see if data is incorporated correctly
Case Study - Evaluation

• Several types of results
  – Independent hardware / software problems (or not)
  – Integration problems (or not)
  – Independent hardware / software long duration problems (or not)
  – Problems detected via the simulation (or not)
    • Utility of these test results is highly dependent on the validity of the simulation (i.e., the assumptions used to create it)
  – Thus, there is no testing ‘panacea’ proposed
Autonomous testing can augment or replace manual and automated testing.

It could:

- Expand on human testing
  - Take human-determined values as starting point, add nearby
- Explore problem space
  - Identify other potential problem areas (random or informed)
- Observation based
  - Observe behavior (user, attacker, etc.) and generate cases
Onboard Maintenance System

• Using the information gained through testing, the creation of an onboard maintenance system may be possible
  – Uses detected faults, knowledge of resolution
  – Implement pre-planned responses or use knowledge base to prevent / resolve issues

• Accelerated testing-gained information and resolutions identified are key to informing operations of this system
Conclusions and Future Work

• An overview of accelerated testing approaches for cyber-physical systems has been presented
• Prior work has been discussed
• Issues with conventional testing techniques have been considered
• A hybrid testing approach has been proposed and evaluated
• Future work: further evaluation of the approach
Thanks & Any Questions?