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?

Background – Cyber-physical Systems

- 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

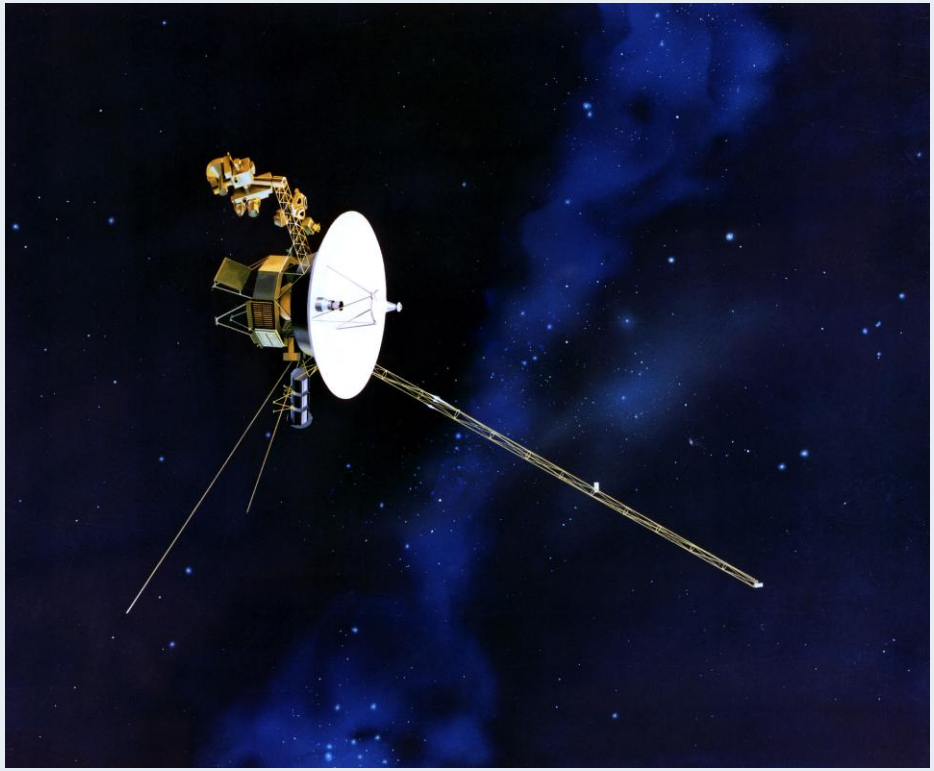
- Even with a combined technique, one cannot expect to fully rapidly test a cyber-physical system
- Increasing testing speed limits the amount of 'real world' operating conditions the hardware-software system is exposed to
- The combined approach provides matching simulated input to both hardware and 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



Voyager Spacecraft (image from jpl.nasa.gov)

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 and Analysis

- 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?