Experimental Test Beds for Embedded & Hybrid Systems

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Foundations of Hybrid and Embedded Software Systems

Experimental Research

Goal: Train new generation of engineers for designing, analyzing, and developing complex, distributed heterogeneous systems

At three levels:

1. Researchers: Experimental Platform for Embedded and Hybrid System Design research, Tool Development, Applications

2. Graduate Education: Task driven research and experiments, Tool Development Research

3. Undergraduate Education: Lab experience for learning and understanding basic embedded and hybrid system characteristics, hands on learning by experimentation
Experimental Platforms at ISIS

- Hardware test beds
  - Complex physical processes
  - Networks of embedded sensors
  - Multiple mobile assets
- Software platform for embedded system design and analysis
  - Model building tools
  - Heterogeneous models of computation
  - Analysis and verification tools (model transformations)
  - Real-time constraint-bound execution environments
  - Code generation tools
  - Application- and task-specific tools (e.g., fault-adaptive control, distributed control, layered fault management)

Test Bed 1: Control of Complex Embedded Systems

- Test bed: sufficiently complex physical process
- Modeling Environment: physical processes + controllers
- Design Tools
- Analysis tools: simulation, symbolic checking, verification
- Run time systems: code generation + experimental tasks
Physical Test Beds

- Three Tank System
- Mobile Robot systems

Software Platforms
(From Model-based Design research)

- Modeling languages for complex hybrid systems + embedded controllers
  - GME: visual modeling tool
  - Ptolemy: models of computation
- Analysis tools
  - Model Transformations
  - Reachability and safety analysis, symbolic model checkers for verification
- Real-time environments for embedded systems
  - QNX or VxWorks based
  - Giotto + e-machines
  - Real-time CORBA based environments
- Automated code generation
  - For various platforms
Example Task (1): Mobile Robot Control

- Robot must navigate and reach target while moving through unknown terrain
- Issues:
  - Terrain not uniform: multi-modal control; autonomous mode switching
  - Fault Detection and Isolation: process, sensor, and actuator faults
  - Fault Adaptive Control: fault identification, controller tuning, and reconfiguration

Example Task (2): Fault-Adaptive Control of Aircraft Fuel System

- Possible Faults:
  1. Degraded or Failed Wing and Fuselage Tank Pumps
  2. Feed Tank and other Valve Degradations
  3. Leaks in Pipes

Hybrid Control based on Tank Levels:
- Supply sufficient fuel
- Maintain aircraft CG
Task: Control of Distributed Parameter Systems

- Test bed: physical systems with distributed parameters – e.g. vibrations, acoustics, fluidics, environmental

- Critical issues at the interface of mechanical/computational systems:
  - Control system design in an embedded computational environment
  - Effects of embedded system limitations on control
  - Leveraging embedded software technologies for control

Experimental Platforms

Experimental test beds of increasing scalability and complexity will be developed

- Simple beam vibration control
- Acoustic target detection
- Complex structural acoustic control (launch vehicle payload fairing)
Test Bed 3: UAV-Based Radio Location

- Multiple Organic Air Vehicles (OAVs)
- Time Difference of Analysis (TDOA) for geo location of objects
- Tracking as object(s) of interest move
- Issues:
  - Model-based design and integration of OAV payload

Example Task: Find a radio source

- Family Radio Systems
  - Detect call button
  - Utilize GPS clock to find relative time of detection of call button
- DSP processing
  - A/D Sample baseband FRS data
  - Detect call signal
  - Communicate TOI (based on GPS clock - perhaps refined) via serial RF to base
- Base Calculation
  - intersection ellipse
  - location
  - coordination redirection
Hardware Platform:
Form Factored Payload

From OAV:
- GPS Location
- Clock
- 5V Power
To OAV:
- Position Control
- Network: RF Modem

TMS320C611
- 500-900 MFLOPS
- 64 MB RAM
- 100K Gate FPGA

A/D Converter
- Dual Channel, 12 bit
- 50 MSample/Sec

Receiver
- First-Cut: FRS

Application to Undergraduate Education

The Curriculum
Challenge-Based Instruction