Automated Model Based Design Process to Evaluate Advanced Component Technologies

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Overview

- Introduction to Autonomie
- Major Steps in Model Based Design
- System architecture for Component Modeling
  - Controller, Actuator, Plant & Sensor
- Plant modeling with varying complexity
  - Links with other commercial tools
- Control Development
- Framework for Model Based Design
  - Model In the Loop
  - Software In the Loop
  - Hardware In the Loop
  - Rapid Control Prototyping
  - Component In the Loop
- Battery In the Loop example
- Summary
Approach

Component Organization

Graphical User Interface

Data Organization

Hardware Modeling & Analysis

Requirements

Engine

Transmission

Vehicle

Hybrid

Control Algorithm Design & Analysis

Requirements

Process

Control

Post-processing Tools
Major Steps in Model Based Design

Software-in-the-Loop
- Algorithm or Controller Model
- Plant Model
- Compiled C-code S-Function
  - Code Generation
  - Execution on Host Computer
  - Non Real Time
  - No I/O

Hardware-in-the-Loop
- Algorithm or Controller Model
- Plant Model
  - Code Generation
  - Embedded Target
  - PC with I/O Boards
  - I/O

Rapid Control Prototyping
- Algorithm or Controller Model
- Plant Model
  - Code Generation
  - Real time simulation target
  - Plant / Prototype
  - I/O

Component-in-the-Loop
- Algorithm or Controller Model
- Plant Model
  - Code Generation
  - Rest of Vehicle is Emulated
  - Entire System is Hardware
  - I/O
System architecture

Flexible system architecture

Controller  Actuator  Plant  Sensor

Example: GM 2 Mode HEV Transmission Plant

Electric Machine #1  Electric Machine #2  Gearbox

Any System can have Subsystems To Accurately Represent Hardware
Plant Models with Different Level of Complexity

- Different models are necessary to study different phenomena
- Detailed models are required when technology cannot be tested or does not exist!
Link with Commercial Off the Shelf Tools

#1 – Develop Model in Native Environment

#2 – Integrate Model in Simulink

#3 – Use Model in Autonomie

COTS
(1) can be used to generate maps
(2) can be run in the Simulink environment
(3) can be run in their own environment (co-simulation)

GT Power, CarSim & AMESim already linked.
Select the Appropriate Level of Modeling

Controllers
- Engine Experts
- Battery, Motor Experts
- Transmission Experts
- Chassis Experts

Plants
- Vehicle Experts

Tools
- Engine Experts
- Battery, Motor Experts
- Transmission Experts
- Chassis Experts

Software
- GAMMA Technologies
- Amesim
- CarSim
Model & Data Requirements
Experts Transfer Systems - Example
Autonomie in the Controls Development Process

- **System Requirements**
  - Sim: Simulation
  - RP: Rapid Prototyping
  - OTRP: On-Target Rapid Prototyping
  - PCG: Production Code Generation
  - SIL: Software-In-the-Loop
  - PIL: Processor-In-the-Loop
  - HIL: Hardware-In-the-Loop

- **System Design**
  - RP

- **Software Design**
  - OTRP

- **Software Integration**
  - SIL

- **Coding**
  - PCG

- **System Integration & Calibration**
  - HIL

**Abbreviations:**
- Sim: Simulation
- RP: Rapid Prototyping
- OTRP: On-Target Rapid Prototyping
- PCG: Production Code Generation
- SIL: Software-In-the-Loop
- PIL: Processor-In-the-Loop
- HIL: Hardware-In-the-Loop
Model-in-the-Loop
Develop Control Algorithm

- simulation

Generic Component System

Information from Other Systems

Controller ➔ Actuator ➔ Plant ➔ Sensor
Software-in-the-Loop
Develop Control Algorithm
 Adding production code to controller model

Generic Component System

Controller ➔ Actuator ➔ Plant ➔ Sensor

RTOS
SIL
AM
CAN
Hardware-in-the-Loop
Develop Control Algorithm
Hardware-in-the-Loop
Develop Control Algorithm

Generic system for HIL

Experiment Control → Generic Component → Experiment Survey

Constraints
Commands Survey & Saturation
Emergency action if E-Stop (actions different based on issues – soft vs. hard E-Stop)

Overwrite
Overwrite manually any commands for debugging and system check

Commands
Hardware startup
Hardware shut down
Hardware mode selection

Survey Logic
Verify if signals are within their operating ranges, e.g., temperature, max current, max speed...
Hardware-in-the-Loop
Using Controller Hardware

Generic system for HIL

Experiment Control → Generic Component System → Experiment Survey

Experiment Setup I/O
- CAN, analog, digital
- Signal conversion (e.g., volt, rpm...)

Plant

Controller Hardware

Can have separate models for actuators and sensors (optional)
Rapid Control Prototyping
Using Plant Hardware
Component-in-the-Loop
Using Hardware for Controller & Plant

Generic system for CIL

Experiment Control -> Generic Component System -> Experiment Survey

Information from Other Systems

Experiment Setup I/O
- CAN, analog, digital
- Signal conversion (e.g., volt, rpm...)

From Experiment Control
To Experiment Survey
Component-in-the-Loop Testing Battery in a Virtual Vehicle

- Implement vehicle controls
- Analyze results
- Compile to target
- HV DC source emulates electric load from vehicle
- CAN communication
Summary

- Establishes tool and framework for enterprise-wide collaboration
- Common framework for all MBD activities
- Provides complete user customization by an open architecture
- Simulates from single components, subsystems to entire vehicles
- Manages models, data, processes, results and control code from research to production