Model-Based Design: Design with Simulation in Simulink

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Outline

- Model-Based Design Overview
- Modelling and Design in Simulink
  - Modelling
    - Physical Systems
    - Control logic
  - Simulation
    - System-level optimisation
    - Verification of design changes
- Summary
Traditional Development Workflow

RESEARCH

SPECIFICATIONS

DESIGN AND IMPLEMENTATION

C/C++
Embedded Software

Algorithm Design

MCAD/MCAE
Mechanical Components

EDA
Electrical Components

INTEGRATION AND TEST
Problems in Traditional Development Workflow

- Requirement Documents
- Paper Specifications
- Physical Prototypes
- Manual Coding
- Traditional Testing

- RESEARCH
- REQUIREMENTS
- SPECIFICATIONS
- DESIGN AND IMPLEMENTATION
- INTEGRATION AND TEST

- C/C++
- Embedded Software
- Algorithm Design
- Embeddable Algorithms
- MCAD/MCAE
- Mechanical Components
- EDA
- Electrical Components

Paper Specifications
Model-Based Design Workflow

Traditional System Development Workflow
1. Research
2. Requirements and Specifications
3. Design
4. Implementation
5. Test and Verification
Model-Based Design: Specifications

**CAPABILITIES**
- Executable specification
- Executable constraints
- Links to requirements

**BENEFITS**
- Early validation and test development
- Clear specification
- Simulate whole system, including environment
- Tight link to requirements
Model-Based Design: Requirements

**Formalize requirements as properties and objectives**

After initialization:

```
if Req occurs then
   within 3 to 7 steps later ...
   Acc needs to be set at least once
```

Model system response bounds

**Trace to requirements in DOORS, Word, Excel, etc.**

**Requirements**

- **5.1 Purpose of the document**
  - **Module ID**: DOX00054
  - **Module Location**: XE/RA/AV/Controller, Derived Requirements
  - **Object ID**: 2
  - **Test Cases**: TestCase1
  - **Object Heading**: Purpose of the document
  - **Object Text**: This document provides the derived software requirements for a reusable attitude controller that will be used in the Altair Project.
Model-Based Design: Design

CAPABILITIES
- Refine model description
- Add fixed point, timing, component interface details

BENEFITS
- Fast design exploration
- Design optimization
- Find flaws before implementation
Model-Based Design: Design

**CAPABILITIES**
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**BENEFITS**
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Model-Based Design: Implementation

CAPABILITIES
• Rapid Prototyping
• Automatic Code Generation:
  • C/C++
  • HDL
  • PLC

BENEFITS
• Eliminate hand-coding
• Eliminate hand-code errors
• Hardware target portability
• Better testability and reuse
• Bridge between domain, software, and hardware knowledge experts
Model-Based Design: Test and Verification

**CAPABILITIES**
- Model Verification
- Software Verification
- Hardware-in-Loop
- Test and Measurement

**BENEFITS**
- Detect errors earlier
- Reduce use of physical prototypes
- Implementations that work first time
- Reuse tests throughout development stages
Building a Wave Farm with Model-Based Design

As engineering tools, MATLAB and Simulink provide significant value. They are just as valuable as innovation tools because they enable us to quickly test ideas that we would otherwise never try.

— Jonathan Fiévez, Carnegie Wave Energy
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Mechanical System Modelling

Simulink
Mechanical System Modelling
Mechanical System Modelling

Simscape
Electrical System Modelling

Bridge Rectifier
(AC to DC)
Electrical System Modelling

Simscape
Electrical System Modelling
Multi-Domain Modelling of Physical Systems

Simscape
MATLAB & Simulink
Control System Design
Defining System Mode Logic

- Define mode logic using state machine in Stateflow
- Generate production code directly from model
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Optimise Entire System

- Use optimisation algorithms to automatically tune parameter values
  - Match response
  - Meet requirements

- Optimise system performance (controller and physical system)

**HEV Model**

- IC Engine On Spd
- IC Engine Off Spd
- Battery Capacity
- Battery Max Discharge Power

**Optimisation Algorithm**

- Parameter Values

**Calculate Cost**

- Fuel Consumed Over 100 Different Drive Cycles

**Motor Torque**

**Motor Speed**
Distributing Simulations with Parallel Computing

- Simulating in parallel
  - Distribute simulations to multiple cores/processors
  - Dramatic speedup for sets of simulations (parameter sweeps, flight cycles optimisations, and more)

\[ \text{for} \quad \text{parfor} \]
Shorten Simulation Times With Parallel Computing

Model:

Problem: Minimize simulation time to run a parameter sweep on the HEV model

Solution: Use Parallel Computing Toolbox to speed up the sweep
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Automatically Run Tests And Document Results

Problem: Evaluate test results quickly to make design changes and document the results

Solution: Use Simulink Report Generator to automatically document tests and results
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Key Points

- Simulink is a multi-domain modelling and simulation environment facilitating Model-Based Design
- Optimise the system-level performance
- Accelerate your development
  - Speed up simulations using Parallel Computing Toolbox
  - Speed-up processes using Simulink Report Generator
Call to Action

Learn more about Model-Based Design with Simulink

- Explore our [website](au.mathworks.com)
  - Contact me:
    - Ruth-Anne Marchant
      - [ruth-anne.marchant@mathworks.com.au](mailto:ruth-anne.marchant@mathworks.com.au)
Q & A