Introduction to Control System Design & Analysis Using MATLAB & Simulink

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Key Takeaways

- Single Environment for Plant Modeling, Controller Design and Analysis
- Efficiently Design Controller Logic using Interactive Design Tools
- Achieve Overall System Performance Goals using Optimization-Based Techniques
Control System Design Process

1. Know your plant/system - Linearization
2. Design the controller with linear plant model
3. Test controller with non-linear plant in closed-loop
4. Add State-machine & Supervisory Logic
5. Test Controller in Real-Time
Multi-Domain Plant Modeling using Simulink and Simscape

- Simulink is an environment used by system and controls engineers for multidomain system simulation & embedded algorithm development
- Simscape enables physical modeling of multidomain physical systems
- Eases process of modeling physical systems
  - Build models that reflect structure of physical system
  - Leverage MATLAB to create reusable models

Demo
Plant Model in Simulink

Simulink Advantages:

- Environment for Model-Based Design for Dynamic and Embedded Systems
- Model, Simulate, Visualize & Analyze Results, Generate Code & Implement
Plant Model in Simscape

Simscape Model Advantages:

- Easier to read than equations
- Quicker to create
- More intuitive – easier to explain to other engineers
Multi-Domain Plant Modelling using Simscape

- Plant Modeling & Linearization
- Controller Design & Stability Analysis
- Closed-Loop System Analysis
- Add State-Machine & Supervisory Logic
- Test Controller in Real-Time

Multidomain physical systems

- Mechanical
- Hydraulic
- Electrical
- Thermal
- Pneumatic
- Magnetic

Custom Domains via Simscape Language

SimMechanics
SimHydraulics
SimPowerSystems
SimDriveline
SimElectronics

Simscape
MATLAB, Simulink
Model System using Measured Data

- **System Identification Toolbox** helps you estimate a model from measured data.
Challenges with Nonlinear Plants

- Finding desired operating points or trimming the plant at multiple operating conditions
- Deriving linearized models at multiple operating points for large & complex system
- Handling systems with strong discontinuities or event-based dynamics
- Performing stability analysis at various operating points
- Checking robustness of a controller against plant uncertainties
Nonintrusive Trimming & Linearization of Plant Models

- Find trim points using optimization methods
- Calculate at specific times or events during simulation
- Automatically generate MATLAB code from the Graphical User Interface
Nonintrusive Trimming & Linearization of Plant Models

- Linearize without having to modify model structure
- Linearize whole model, portion of model, single block, or subsystem
- Specify linearization behavior of any number of blocks in the model
Simulation-Based Computation of a Simulink Model Frequency Response

- Compute frequency response for models with strong discontinuities or event-based dynamics
- Verify results of a linearization
- Study the effects of excitation signal amplitude on nonlinear system’s gain and phase characteristics

Plant Modeling & Linearization

Controller Design & Stability Analysis

Closed-Loop System Analysis

Add State-Machine & Supervisory Logic

Test Controller in Real-Time
Easy Tuning of Single-Loop and Multi-Loop Controllers Directly in Simulink

- Tune gain, transfer function, zero-pole-gain, state-space, and PID blocks in SISO loops
- Automatically identify relevant control loops and launch preconfigured session of SISO Design Tool
- Use graphical, automatic, and optimization-based tuning methods
- Save design for easy retrieval and update of Simulink controller parameters
Interactive Tuning of PID Controllers

- Plant Modeling & Linearization
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- Demo
Controller Tuning using Optimization Based Techniques

- Tune model parameters using numerical optimization to meet desired system performance

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1. **Plant Modeling & Linearization**
2. **Controller Design & Stability Analysis**
3. **Closed-Loop System Analysis**
4. **Add State-Machine & Supervisory Logic**
5. **Test Controller in Real-Time**

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**Demo**
Checking Robustness of Controller Against Plant Uncertainties

- Capturing plant model uncertainty
- Worst-Case Stability and Performance Analysis of Uncertain Systems
- Automatic Tuning of Centralized and Decentralized Control Systems

```
% Create uncertain parameter a = 2 +/- 1
a = ureal('a',2);
% Create a second order transfer function
% with uncertain parameter a
sys = tf([1 3 0],[1 2 a]);
% Plot the worst case gain
wcgainplot(sys,{1 100})
```
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Design & Simulate State Machines and Control Logic using Stateflow

- Stateflow® extends Simulink® with a design environment for developing complex state charts and flow graphs in a natural, readable, and understandable form.
Real-time Testing & HIL Simulation

- Run Simulink models in hard real-time using xPC Target Turnkey solution
- Complete hardware-software solution to perform rapid-control prototyping or hardware-in-loop testing
Summary

Plant Modeling & Linearization

Controller Design & Stability Analysis

Closed-Loop System Analysis

Add State-Machine & Supervisory Logic

Test Controller in Real-Time

Explore & Research

Design & Development

Go Real Time