Scaling Up System Modeling with Simulink

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System modeling has become integral part of complex projects
Challenges for a System Designer

- Conceptualize the product before development
- Test the feasibility of specification at design stage
- Validate the design
- Test the system in real life scenarios
- Reuse / share work with teams
Demo: Airport Conveyor Belt System

Conveyor belts are used for:

- Placing new luggage onto the conveyor belts
- The pickup of luggage by travelers

System Modeling:

- Modeling conveyor belt motion
- Modeling the motion of luggage on the conveyor belt
- Controlling the motion of luggage (influx and outflow)
Traditional System Design Process

RESEARCH

SPECIFICATIONS

REQUIREMENTS

DESIGN

EDA
Electrical Components

Algorithm Design
Embeddable Algorithms

MCAD/MCAE
Mechanical Components

IMPLEMENTATION

C/C++
Embedded Software

INTEGRATION AND TEST
Model-Based Design Process

- RESEARCH
- REQUIREMENTS

DESIGN
- Environmental Models
- Mechanical
- Electrical
- Control Algorithms
- Supervisory Logic

REAL-TIME TESTING
- C, C++
- VHDL, Verilog
- Structure d Text
- MCU, DSP, FPGA, ASIC, PLC

TEST & VERIFICATION
Demo: Airport Conveyor Belt System
Agenda

How to model different kinds of systems using Simulink?

How to build and manage large model and associated data?

How to improve simulation performance?
Agenda

How to model different kinds of systems using Simulink?
Simulink is the platform for modeling dynamic systems

- **Block-diagram environment**
- **Model, simulate, and analyze multi-domain systems along with control algorithm**
- **Model, simulate and analyze Discrete Event Systems**
- **Platform for Model-Based Design**
Temperature (actuator) Control Algorithm

- **Heater ON**: Diff (between 20 – 200) -> Blower = 100%
- **AC ON**: Diff (between 15 – 20) -> Blower = 80%
- **Blower ON**: Diff (between 10 – 15) -> Blower = 60%
- **Blower OFF**: Diff (between 5 – 10) -> Blower = 40%
- **Heater & AC OFF**: Diff (between 1.5 – 5) -> Blower = 20%

**Diff = | Setpoint – Current Temp |**
Modeling and simulating combinatorial and sequential decision logic with Stateflowc

Extend Simulink with state charts and flow graphs

Design supervisory control, scheduling, and mode logic

Model state discontinuities and instantaneous events
Modeling and simulating combinatorial and sequential decision logic with Stateflow
Modeling multi-domain physical systems using Simscape

- Enables physical modeling (acausal) of multi-domain physical systems

- Eases process of modeling physical systems
  - Built based on law of conservation of energy

- Used by system and control engineers to build models with the same structure as the physical system
For more information: Dedicated session on physical modeling

Modeling and Simulation of Electromechanical Systems
16:45–17:45

Physical systems are multidomain in nature. It is always a challenge to both conceptualize the design based on schematics and analyze the interactions between different domains. Simscape™ can help you build a model of a system just as you would assemble a physical system, by providing a single environment for modeling and simulating multidomain physical systems.

Join this session to see how to:

- Model and simulate an electro-mechanical system
- Import a CAD model into SimMechanics™ and perform multi-body dynamic simulation
- Design power electronics converters
- Optimize the model parameters to meet the desired requirements
- Execute the model of the electro-mechanical system in real time
Demo: Airport Conveyor Belt System

Agent-Based Modeling of an Airport Conveyor Belt System
Airport Conveyor Belt System

Time-Based Simulation

- Simulation of motion of conveyor belt system that define motion of the luggage.

Event-Based Simulation

- Simulation of luggage transfer on the conveyor belt system
  - Random baggage arrival and pickup.
  - Transfer of luggage between belts depending on belt capacity.
Discrete Event System

Main Belt

Feeder Belt

Generate discrete items of luggage

Time duration based on uniform random sequence
SimEvents

Some libraries are missing repository information. Fix

- Fuzzy Logic Toolbox
- HDL Coder
- HDL Verifier
- Image Acquisition Toolbox
- Instrument Control Toolbox
- Model Predictive Control Toolbox
- Neural Network Toolbox
- OPC Toolbox
- Phased Array System Toolbox
- Report Generator
- Robotics System Toolbox
- Robust Control Toolbox

- SimEvents
- SimRF
- Simscape
- Simulink 3D Animation
- Simulink Coder
- Simulink Control Design
- Simulink Design Optimization
- Simulink Design Verifier
- Simulink Desktop Real-Time
- Simulink Extras
- Simulink Real-Time
- Simulink Support Package for Arduino Hardware
- Simulink Test
- Simulink Verification and Validation
- Stateflow
- System Identification Toolbox
- Vehicle Network Toolbox
- Vision HDL Toolbox
- Recently Used Blocks

Design Patterns

Composite Entity Creator
Composite Entity Splitter
Design Patterns
Discrete-Event Chart
Entity Gate
Entity Generator
Entity Multicast
Entity Queue
Entity Replicator
Entity Server
Effect of communication delays on an ABS Control System using SimEvents
Optimizing Shared Resources in a Batch Production Process using SimEvents
Simulation of scheduler of a multi-core control system using SimEvents
Model-Based Approach for Analysis of In-Vehicle CAN Partial Networks Power Consumption
16:00–16:30

The need for improved vehicle energy efficiency has increased greatly in recent years along with regulatory fuel economy standards. One key aspect of energy efficiency for both conventional and alternative propulsion vehicles is the energy efficiency of the electrical architecture. In the design of electrical architectures there are several techniques available to increase the energy efficiency. One technique is to manage CAN serial data communication by using Partial Networks. This presentation describes a model based approach for simulating the vehicle network behavior when CAN Partial Networking is used as the strategy for need based ECU activation. The simulation results will in turn provide ECU power consumption data to support various electrical architecture design decisions.
To Summarize..

Simulink is a single simulation platform for modeling and simulating dynamic systems.

Equations

$$V = K \omega + R i + L \frac{\delta i}{\delta t}$$

$$T = K i - b \omega - J \frac{\delta \omega}{\delta t}$$

Sequential Logics: Stateflow

Multi-domain Physical Systems

Discrete Event Systems
Agenda

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How to build and manage large model and associated data?

How to improve simulation performance?
How to build and manage large model and associated data?
What is Large Scale Modeling?

- Project that is too big for a single person to know all the details
- Usually comprised of a combination of:
  - >10,000 blocks in one model
  - >10 custom libraries linked
  - >5 engineers editing one model
  - >15 engineers using one model
  - >20 components or models
- Requires high degrees and overhead of coordination
  - Multiple disciplines, teams, sites or organizations
  - Models reused throughout life cycle
  - Models have different versions
  - Multiple tool versions (internal and external)
- Large organizations are up to 100x beyond this
Essential Technologies for Large Scale Modeling

- **Componentization**
  - Reduce overall complexity by solving smaller problems
  - Facilitate concurrent teamwork and lower file contention
  - Permit component test and isolate behaviors
    - Eliminate re-test for unchanged components

- **Managing Variants**
  - Creating and maintaining different variants of same model.

- **Sharing**
  - Sharing your algorithm within teams/ organizations.
  - Protecting your Intellectual Property.

- **Coordination**
  - Version control and configuration management
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Single Engineer Vs Team
Partitioning a Model using Model Blocks
Partitioning a Model using Model Blocks
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One model for many systems
- Variant Interfaces
- Variant Implementation
Simulink Block Variants

- One platform with variants

2 cylinders
4 cylinders
6 cylinders
8 cylinders
Variant Subsystems

One car model ➔ four car “types”
Variants
Advantages of using Variants

• Variants provide you a way to design one model for many systems.
• You can rapidly prototype design possibilities as variants without having to comment out sections of your model.
• If a model component has several alternative configurations, you can efficiently explore these varying alternatives without altering the fixed, unvarying components.
• You can use different variant configurations for simulation or code generation from the same model.
• You can simulate every design possibility in a combinatorial fashion for a given test suite.
• If you are working with large-scale designs, you can distribute the process of testing these designs on a cluster of multicore computers.
Essential Technologies for Large Scale Modeling

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  - Version control and configuration management
Sharing models with access privilege
Protecting your Intellectual Property (IP)

“A protected model provides the ability to deliver a model without revealing the intellectual property of the model.

A protected model is a referenced model that hides all block and line information.

Protection available for read-only view, simulation, and code generation.

If you choose password protection for one of these options, the software protects the supporting files using AES–256 encryption.

“We’ve devised a new security encryption code. Each digit is printed upside down.”
Protecting your Intellectual Property (IP)
Essential Technologies for Large Scale Modeling

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- Managing Variants
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  - Sharing your algorithm within teams/organizations.
  - Protecting your Intellectual Property.

- Coordination
  - Version control and configuration management
Single Design Engineer

Key concerns

- **Design**
  - Requirements
  - Design techniques
  - Testing
  - ....

- **File management**
  - Simulink models
  - Libraries
  - Model data
  - Test scripts
  - Utility files i.e. setup scripts
  - Reports
  - ....
Team of Design Engineers

Key concerns

- **Design**
  - Domain complexity
  - Component testing
  - ...

- **File management**
  - File synchronization
  - Change tracking

- **Process**
  - Revision control
  - Company standards
  - …
Incremental versions contained a bug, or were incompatible with other files.
Simulink Projects: Aims

- Create an environment that supports adopting best practices
  - Component-based modeling
  - Peer review workflow
  - Simplified configuration management
  - Integration with external data management tools

- Make it easy for everyone on the team to work in the same way
  - Standard way to access to company standard tools and libraries
Simulink Project
Agenda

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What is Simulation?

Creating Simulations

Dr. Richard Gran

Video Courtesy: “What is Simulation?” by Dr. Richard Gran, director (ret.), Advanced Concepts, Grumman, and member of the Apollo Lunar Module Digital Autopilot design team

Who plays a key role in the simulation?
What does a Simulink solver do?

- Control Timing

![Clock image](image)

Major Time Steps
Minor Time Steps

- Perform Integration
Challenges faced by the engineers while performing simulation

- Choosing the right solver
- Speeding up simulations
- Identifying and fixing the bottlenecks during simulation
- Speeding up design optimization and multiple simulations
Using Auto Solver to Select Suitable Solver
Examining Model Dynamics Using Solver Profiler
Challenges faced by the engineers while performing simulation

- Choosing the right solver

- Speeding up simulations

- Identifying and fixing the bottlenecks during simulation

- Speeding up design optimization and multiple simulations
Let’s look at an example model to see how the Simulink Accelerator can speed up simulations.
Challenges faced by the engineers while performing simulation

- Choosing the right solver
- Speeding up simulations
- Identifying and fixing the bottlenecks during simulation
- Speeding up design optimization and multiple simulations
Let’s run the Performance Advisor on the model
Challenges faced by the engineers while performing simulation

- Choosing the right solver
- Speeding up simulations
- Identifying and fixing the bottlenecks during simulation
- Speeding up design optimization and multiple simulations
How can we speed up design optimization tasks?

Using Fast Restart
- Fast Restart eliminates the recompilation time between simulation runs
- Especially useful for calibration workflows where you are tuning block parameters between runs
Running multiple simulations in parallel on a multicore desktop
The Mechanics of `parfor` Loops

```matlab
% simOutput = cell(1, 10)
parfor i = 1:10
    ...
    simOutput(i) = sim(mdlName);
    ...
end
```

Pool of MATLAB Workers
Scaling up to MATLAB Workers on a Cluster
What next?

Kindly refer to “Improving Simulation Performance in Simulink” white paper

More info on choosing the solver
Quick Summary

How to model different kinds of systems using Simulink?
- Multi-domain modeling using Simscape
- Modeling decision logic based systems using Stateflow
- Modeling discrete event systems using SimEvents

How to build and manage large model and associated data?
- Componentization using Model Referencing
- Managing multiple variants using Variant subsystems
- Protecting Intellectual property(IP) using protected models
- Team Collaboration using Simulink Projects

How to improve simulation performance?
- Choosing right solver using Auto Solver & Solver Profiler
- Identifying and fixing bottle necks using Performance Advisor
- Speeding up multiple simulation using Fast Restart and Parallel Computing
Thank You