MATLAB EXPO 2021

외부 시뮬레이션 툴과 Simulink와의 통합

강효석





Key Takeaways

Simulink is an integration platform for simulating your complex, heterogeneous, and multi-domain systems:

- Standard-based interfaces to integrate 3rd party simulation tools/models
- Co-simulation numeric robustness with automatic signal compensation
- Bringing in custom C/C++ code made easy
- Utilizing parallel simulation capabilities to speed up system-level simulations



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Motivation

System-level simulation is becoming pervasive at your product development cycle



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Motivation

System-level simulation is becoming pervasive at your product development cycle



Motivation

System-level simulation is becoming pervasive at your product development cycle



Motivation

Increasing challenges when simulating complex systems

- Multi-domain, inter-disciplinary design
- Model re-use among suppliers, clients and collaborators while hiding design details
- Performance: the need to speed up simulations for quick insights



THE CHALLENGE OF FULL VEHICLE SIMULATION

Model-Based Agility with Ford Automated System Simulation Toolchain (FASST)

MathWorks Automotive Conference 2020

Agenda







Interfaces to External Simulation Tools





White-box and Black-box Integration

- White-box (tool-coupling)
 - Both Simulink and the external tool are running during simulation

- Black-box (compiled model)
 - Only Simulink is running during simulation
 - The 3rd party model is a component inside Simulink





* With or without solver

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White-box and Black-box Integration

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 - The 3rd party model is a component inside Simulink

- Standard-based interfaces used for both styles
 - S-functions
 - Functional Mockup Interface (FMI)



* With or without solver

S-functions Interface

- Build custom dynamic systems in MATLAB, or C/C++
- Supports all Simulink semantics
- Well validated by industry for 20+ years
- The de facto standard to couple external tools with Simulink



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S-functions Interface

- Many of the MathWorks' Connection Partner simulation tools (150+) provide prebuilt co-simulation interfaces using S-functions
- S-functions based cosimulation interface is also available with some nonpartner's tools

Third **T**FILTER Third-Party rFpro Photo-re FILTER Third-Party rFpro all FTire and FTire/li photo-re Physical tire mode FILTER Compar FTire (Flexible Rin for vehicle comfort **Biomechanics of** Riviera-Biomechanical and High-pe Company: cosin s Biomechanics of E Riviera i Gas Dynamics ar model consists of batch pr Dynamic simulatio Company: BoB B Compai ACUSYS simulate Bonsai network, induced t Saber Deep reinforceme Design Company: SATE The Bonsai platfo Saber GENESYS complete developr Compai Software for mode Company: Bonsai **GENESYS** deliver Sensors **Cadence Virtuos** collaboratively buil SEWES Accelerate proces Company: Vitech SEWES Designed to help number **GL Studio** the advanced desi Compar Transition high-end Company: Caden GL Studio ® is a p SIDLAB CANoe their software proc Simulati Tool for design an Company: The Di SIDLAB CANoe is a distrib design a gPROMS Block C application behavior Compai Process modeling, Company: Vector gPROMS is an ad Siemen CarMaker for use complexity involvir Providin Open integration a Company: Proces The tire CarMaker for Simu and Simulink® mo GT-SUITE Engine, powertrain, and vehicle Company: IPG A CarSim, TruckSim, BikeSin Simulation of the vehicle dynamics for SIL, HIL, and Driving Simulators

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	Simcenter Amesim Mechatronic system simulation software
	Simcenter Amesim™ software is an integrated, scalable mechatronic system simulation platform that allows design engineers to virtually assess and optimize systems' performance.
	Company: Siemens Industry Software
	Simcenter MAGNET Low-frequency electromagnetics simulation software
	Simcenter MAGNET 2D/3D is a powerful simulation software which engineers and scientists worldwide use for the design of motors, sensors, transformers, actuators, solenoids or any component with permanent
	Company: Mentor, a Siemens Business
	SIMPACK Complete multibody simulation in combination with MATLAB
	SIMPACK is a general-purpose, nonlinear, 3D multibody simulation tool. It is designed to simulate mechanical systems, analyze vibrational behavior, calculate forces and accelerations, and describe and
	Company: SIMPACK AG
	SIMTEST Toolbox
	Vibration analysis and control for multi-axis simulation testing
	dynamic analysis and control. It provides advanced vibration analysis and control
	Company: Simulation Techniques, Inc.
	SimulationX
	High-end modeling tool for simulating nonlinear, dynamic effects
	SimulationX is ITI's multiphysics software tool for system simulation. It is used for modeling, analyzing, and optimizing complex, dynamic, nonlinear systems. Simulation models are defined interactively
2	Company: ITI GmbH
	SimWise 4D Simulation and validation of functional performance for mechanical parts and assemblies
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ly no	n-linear vehicle component that has a significant effect on the behavior of a vehicle. As the numb

https://kr.mathworks.com/products/connections/search-products.html?q=&fq[]=connections-task:sysmod&page=1 11

To Learn More to Use S-functions to Communicate with an External Application

- Example template to use S-functions as the tool-coupling interface
 - Available on "Guy on Simulink"



Guy on Simulink Simulink & Model-Based Design

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< MATLAB Online, MATLAB Mobile, MATLAB... Simulation Data Inspector in R2018a >
                                              Communicating with an External Application for Co-Simulation
Recent Posts Archive
                                              Posted by Guy Rouleau, May 1, 2018
                                                                                                                      ● 128 views (last 30 days) | ▲ 0 likes | ₱ 7 comments
22 DEC Configuring a Simulink Model for
AUTOSAR
                                              Today I am describing an example that I recently submitted to MATLAB Central and GitHub with the help of my colleague Haihua Feng: Example
                                              implementation of Co-simulation using Simulink.
2 NOV Creating Custom Gauges
14 OCT Deploying the Virus Spread Simulator
                                              In case you did not know, MathWorks' website lists a lot of third-party modeling and simulation tools from MathWorks Connection Partners.
Using Simulink Compiler
5 AUG Getting Started with Simulink Compiler
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16 JUN Creating and Editing Simulink Models in
MATLAB Online!
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Simulink Tips
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                                                                                          CosiMate
                                                Lab Experiments
                                   more ¥
                                                                                          CosiMate is a co-simulation backplane that enables multiple simulators and models to
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Functional Mock-up Interface (FMI)



- FMI is a tool independent specification to support dynamic system simulation
 - A FMU is a ZIP file packaging a model exported in FMI format
- A growing list of tools of supporting FMU export or / and FMU import
 - https://fmi-standard.org/
- Simulink can import both co-simulation and model-exchange FMUs for both FMI 1.0 and FMI 2.0

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Demo - Virtual Vehicle ADAS Applications

Integrating external components using S-functions and FMU



Demo - Virtual Vehicle ADAS Applications

Integrating external components using S-functions and FMU







Robust Co-simulation





Co-simulation

- A frequently used method to bring models of external tools into Simulink
 - Each co-simulation component has its own solver
 - Can be implemented either white-box or black-box style
- Co-simulation components can run in parallel freely between communication macro steps





Co-simulation Numeric Behavior

- Model integration is more than coupling the signals
- Potential error when coupling continuous signals
 - Discretized and delayed crossing cosimulation boundary
 - Non-compensated signals could lead to accuracy loss or even system instability



The un-compensated signal (red line) deviates from the ideal, continuous signal (blue line) due to discretization

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Robust Co-simulation

- Automatic and manual mechanism to compensate the discretized continuous signals
 - Choice of linear or high order extrapolation compensation methods
- More robust co-simulation results compared to un-compensated cosimulation





The compensated signal (black line) with simple linear extrapolation is closer to the ideal, continuous signal (blue line) than the uncompensated, discretized signal (red line)

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Custom Code Integration





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Custom Code Integration

Model-Based Design



Custom Code Integration

Model-Based Design



C/C++ Libraries



Custom Code Integration

- Versatile ways to integrate your custom code
 - Simply calling your function
 - Reuse your code as a Simulink library
 - Scripting algorithm with discrete states
 - Dynamic system creation



Demo - Virtual Vehicle ADAS Applications

• Integrating custom C code for lane marker detection



Demo - Virtual Vehicle ADAS Applications

• Integrating custom C code for lane marker detection







Simulation Scalability





- System-level simulation problems may involve a large number of simulation iterations due to the complexity of design combinations
- Complex system simulation takes time to execute
- The capability to scale up is a must-have of an integration platform to deliver quick simulation insights

Full vehicle simulation

10 drive cycles10 weather conditions10 vehicle loadings10 gear ratios10 tire sizes

-> 100,000 simulations



• The same code for desktop simulation and running in the cloud



Manage and visualize the simulations as the simulations are progressing



• Manage and visualize the simulations as the simulations are progressing



 Move the simulation to the Cloud by leveraging a Prebuilt Cloud Configuration via Reference Architecture



User Story - Model-Based Agility with Ford Automated System Simulation Toolchain (FASST)



https://kr.mathworks.com/videos/model-based-agility-with-ford-automated-system-simulation-toolchain-fasst-1592849717839.html

Summary

As an integration platform Simulink provides key capabilities to scale up your complex, system-level simulations:

- Standard-based interfaces to integrate 3rd party simulation models
- Co-simulation numeric robustness with automatic signal compensation
- Bringing in custom C/C++ code made easy
- Utilizing parallel simulation capabilities to speed up system level simulations



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Thank you



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