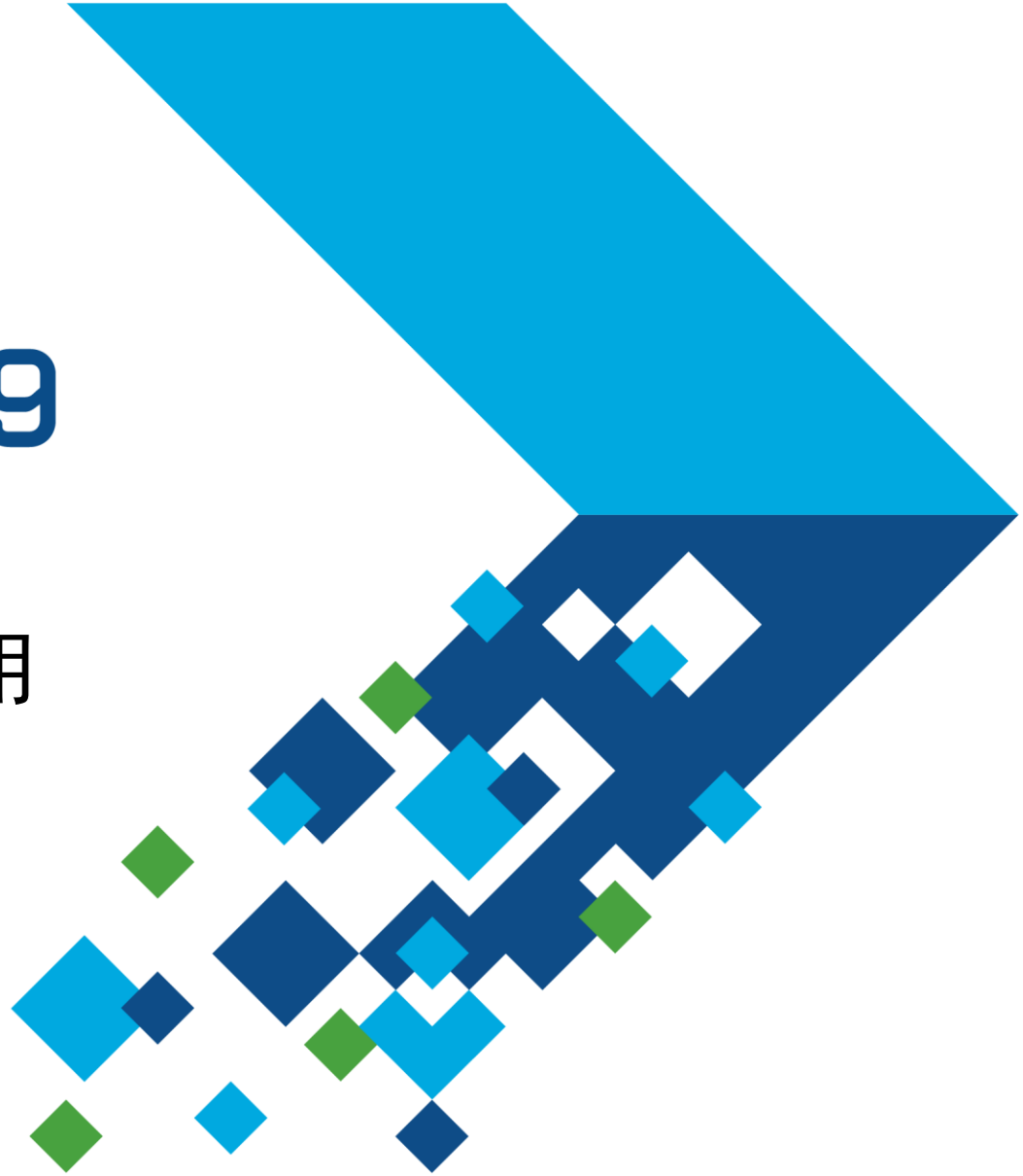
MATLAB EXPO 2019

Simulink作为企业仿真平台的应用

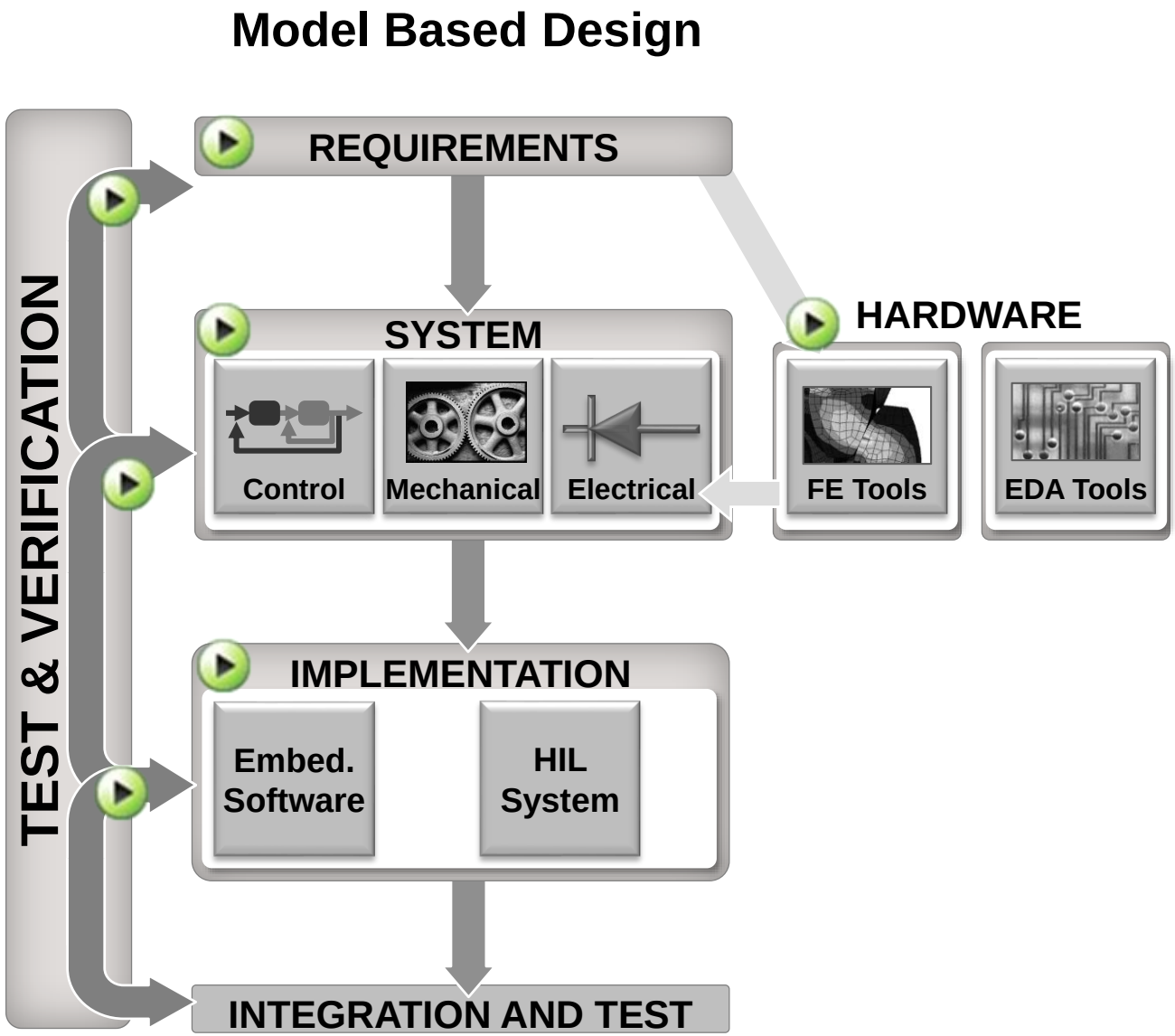
吴菁

MathWorks China



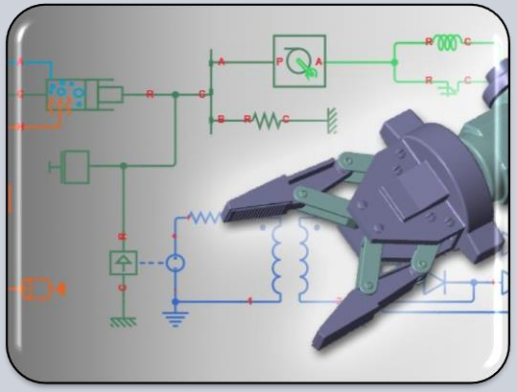
企业仿真平台

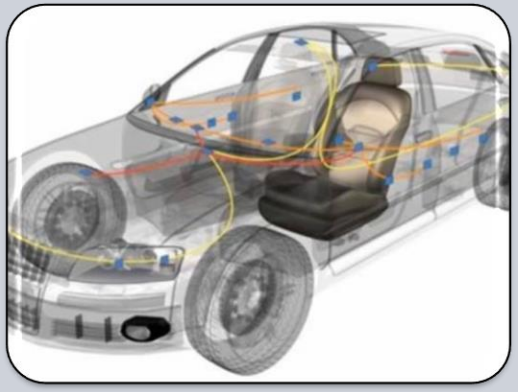
- 企业 – 不同规模的业务或项目
- 仿真 – 通过计算评估系统行为
- 平台 – 协同设计工作流程

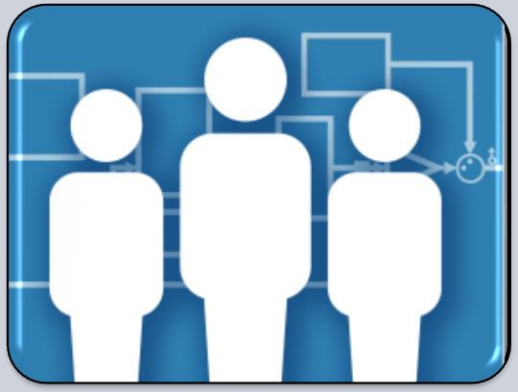


Simulation

企业仿真平台的重要能力





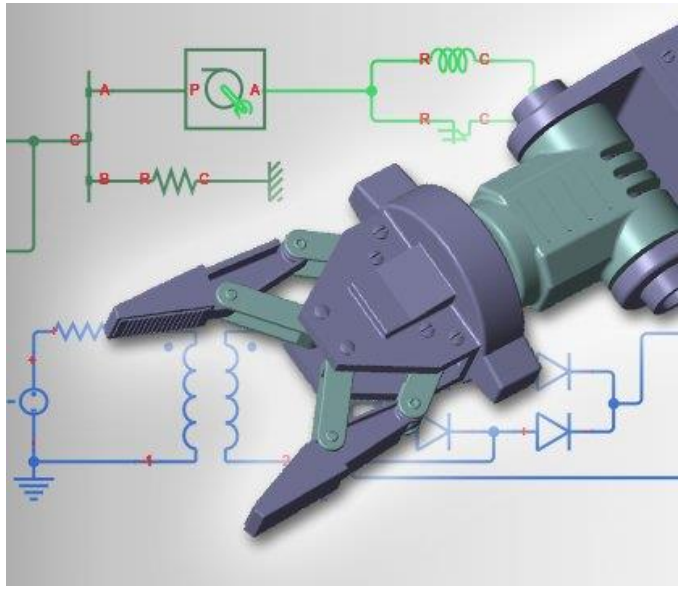


多域
建模

仿真
集成

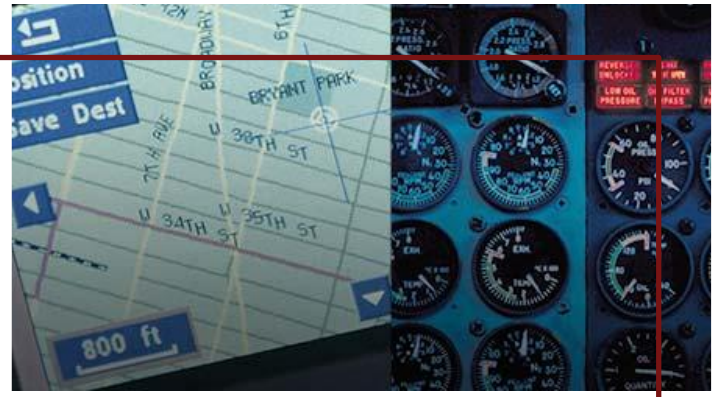
协同
设计

多域建模

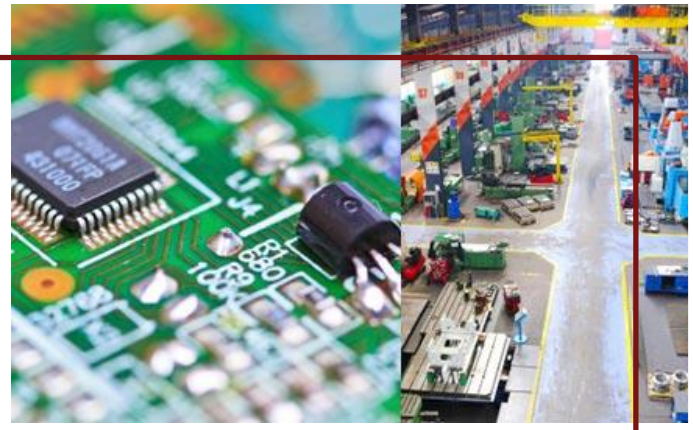


Simulink的多领域建模能力

动态系统

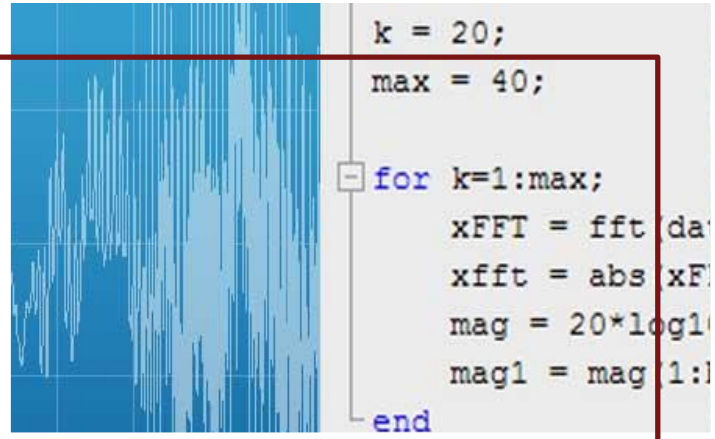


状态机



离散系统

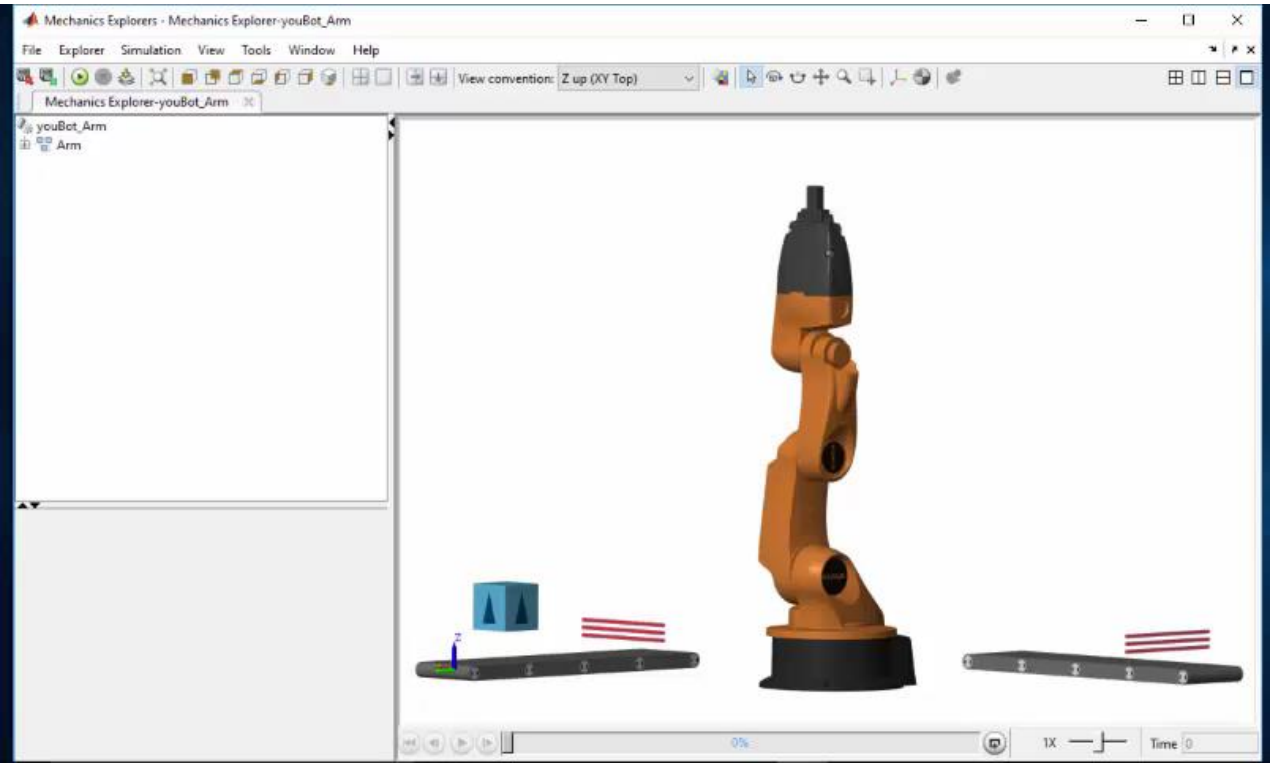
物理系统



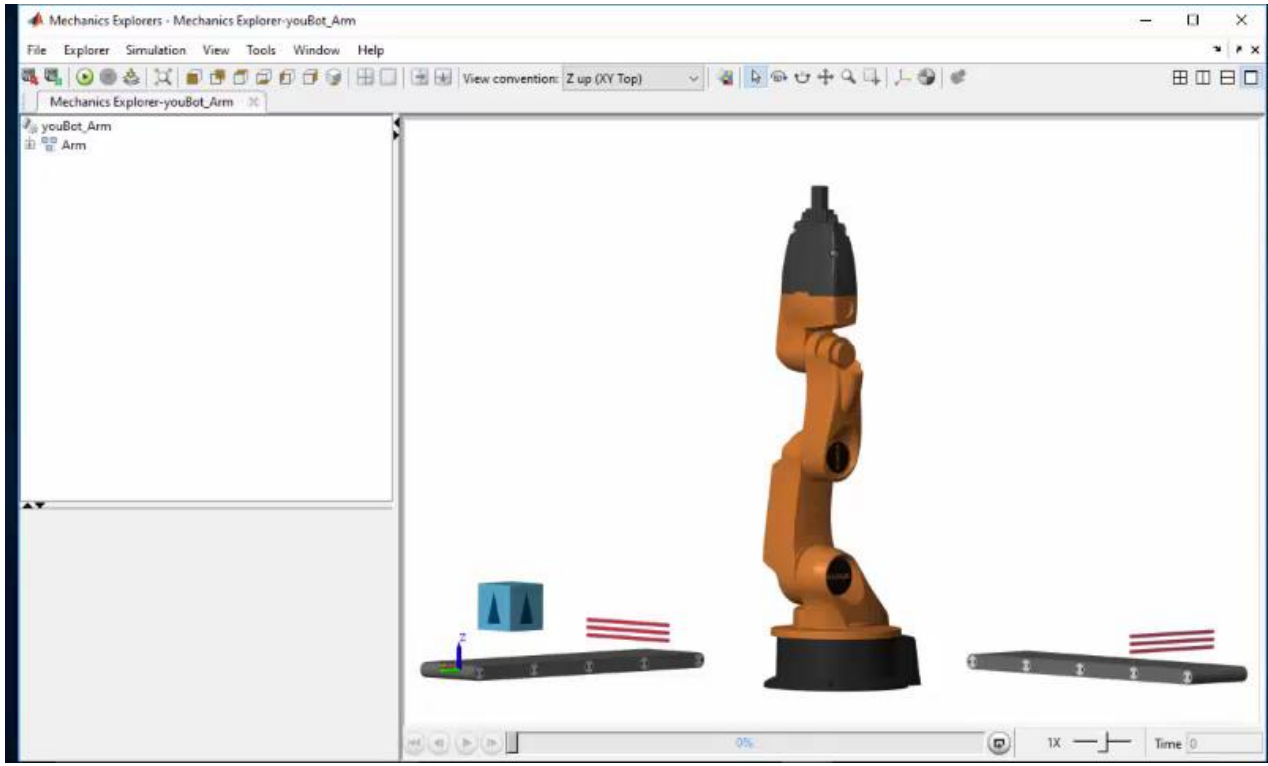
面向对象

机械臂的多领域仿真

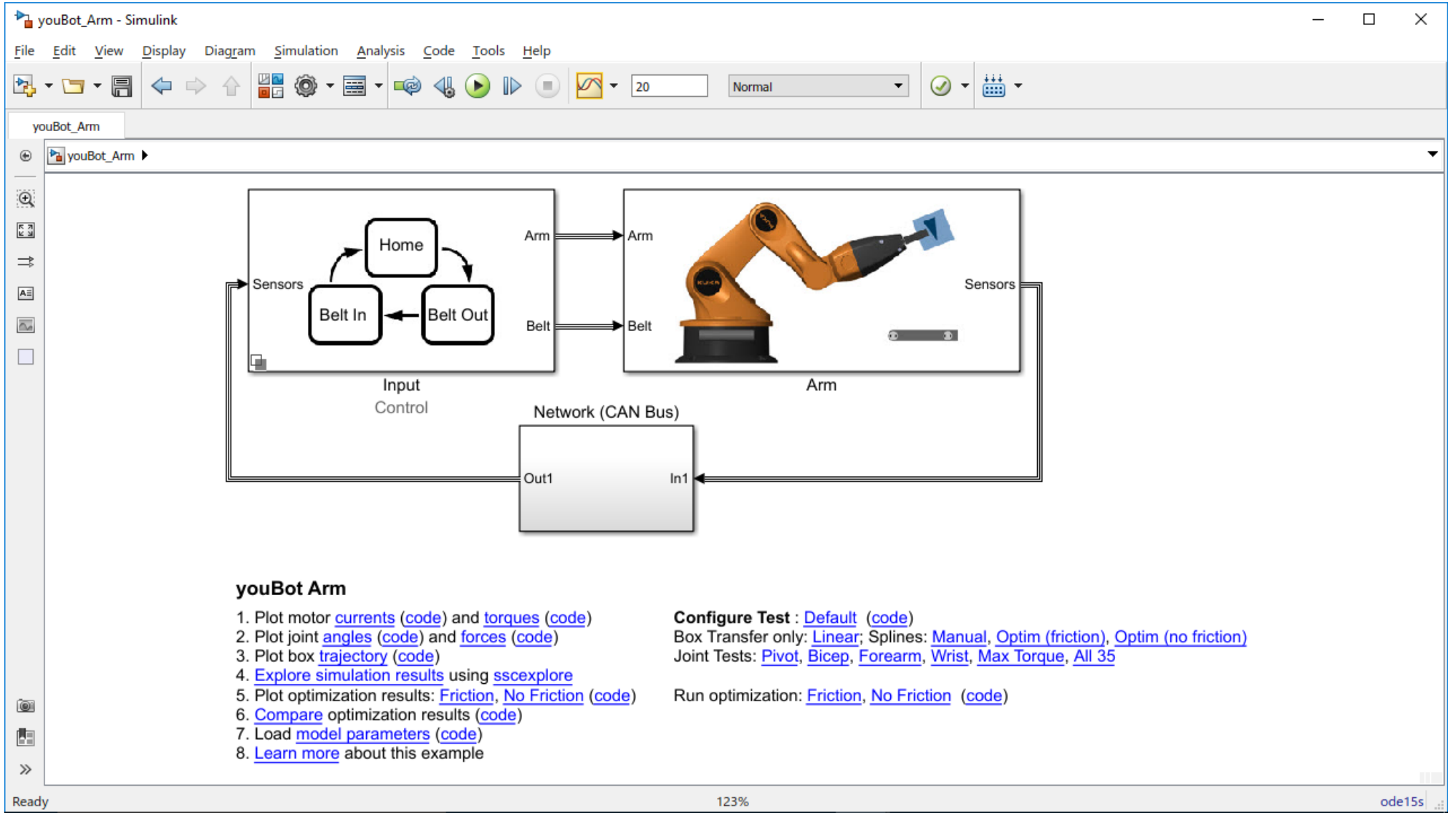
不带通讯网络的模型



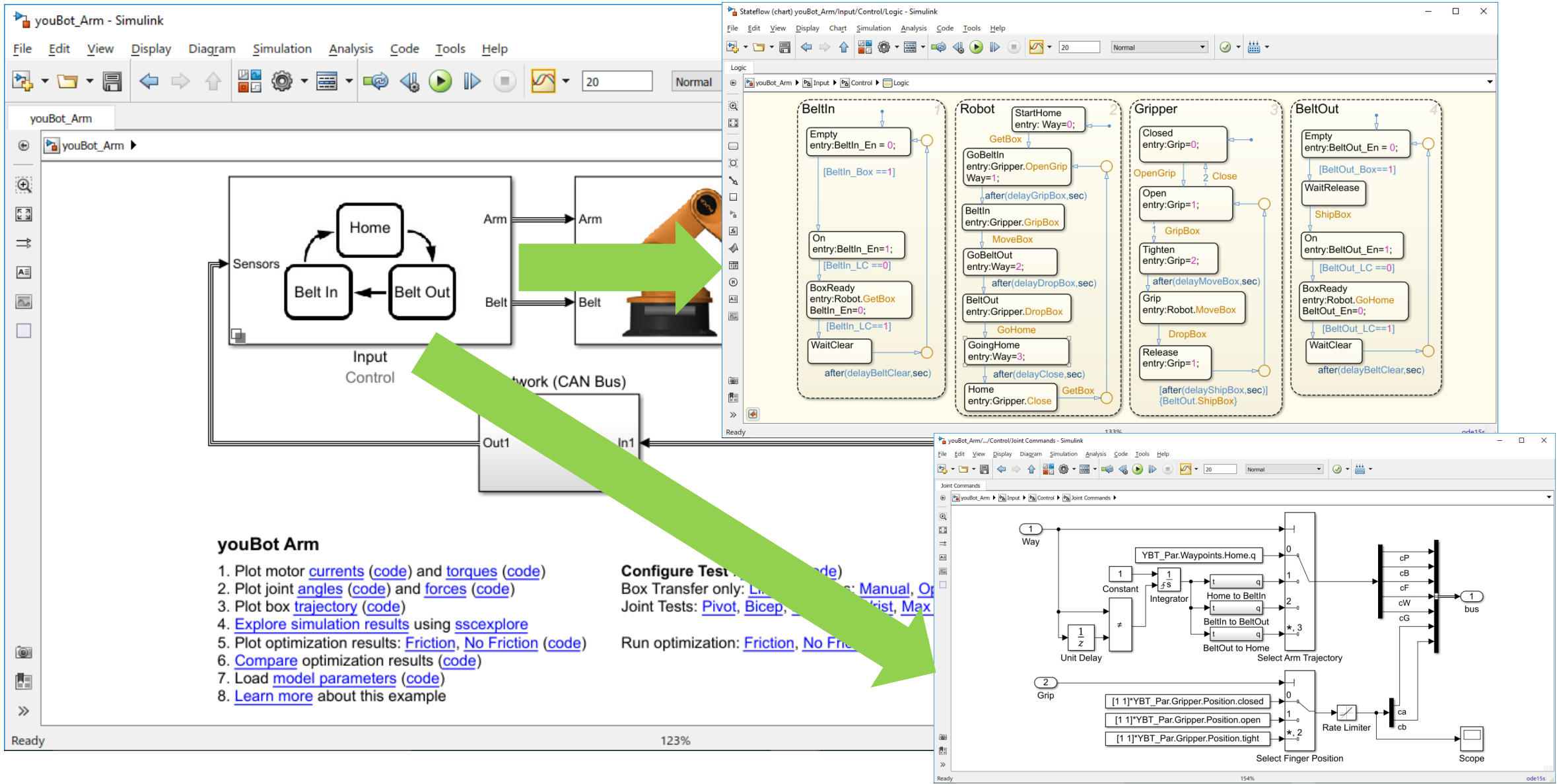
带通讯网络的模型



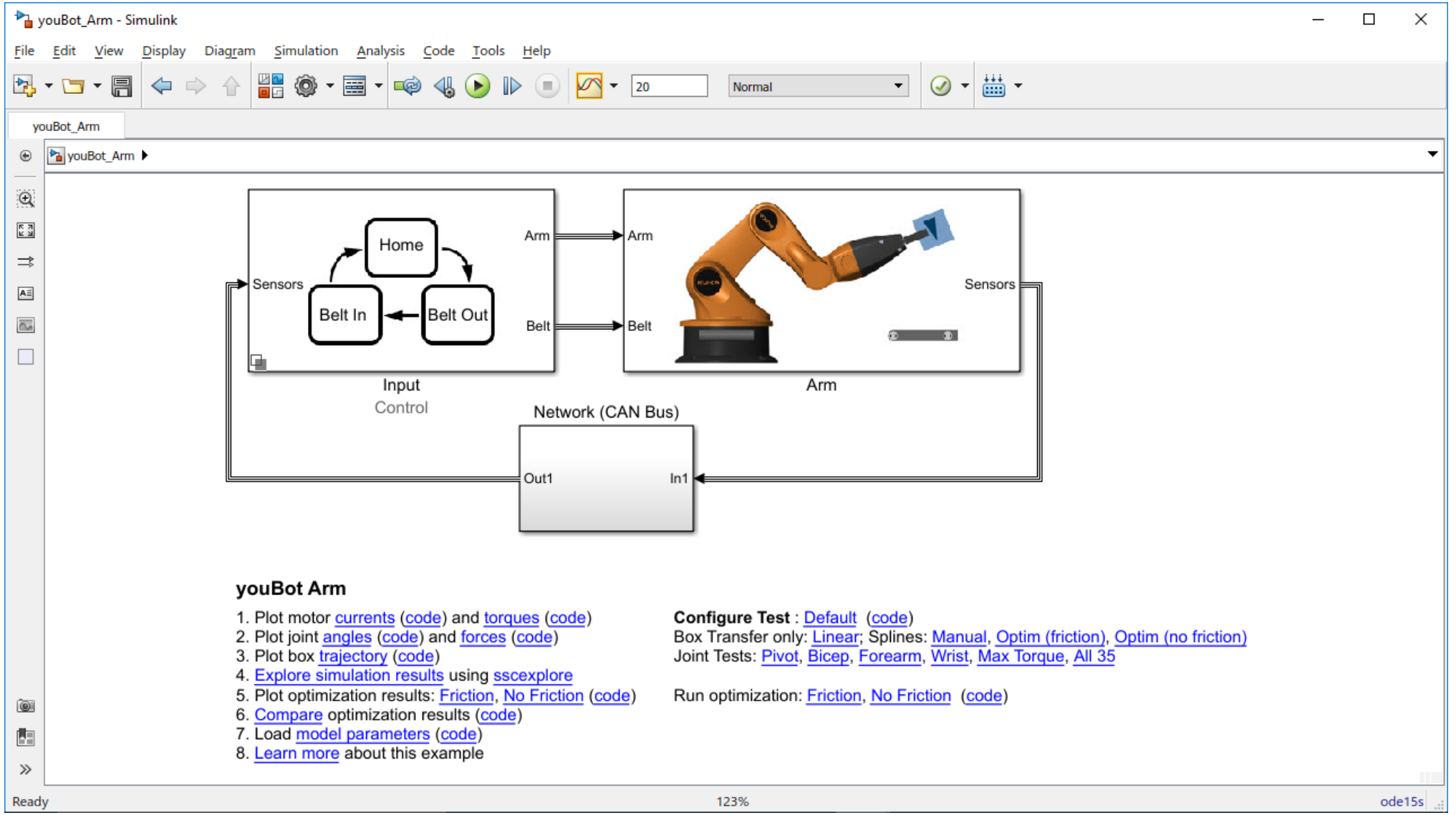
机械臂的多域模型


youBot_Arm - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
20
Normal
youBot_Arm
youBot_Arm
Home
Sensors
Belt In
Belt Out
Arm
Belt
Input
Control
Arm
Arm
Belt
Sensors
Network (CAN Bus)
Out1
In1
youBot Arm
1. Plot motor currents (code) and torques (code)
2. Plot joint angles (code) and forces (code)
3. Plot box trajectory (code)
4. Explore simulation results using sscexplore
5. Plot optimization results: Friction, No Friction (code)
6. Compare optimization results (code)
7. Load model parameters (code)
8. Learn more about this example
Configure Test : Default (code)
Box Transfer only: Linear; Splines: Manual, Optim (friction), Optim (no friction)
Joint Tests: Pivot, Bicep, Forearm, Wrist, Max Torque, All 35
Run optimization: Friction, No Friction (code)
Ready
123%
ode15s

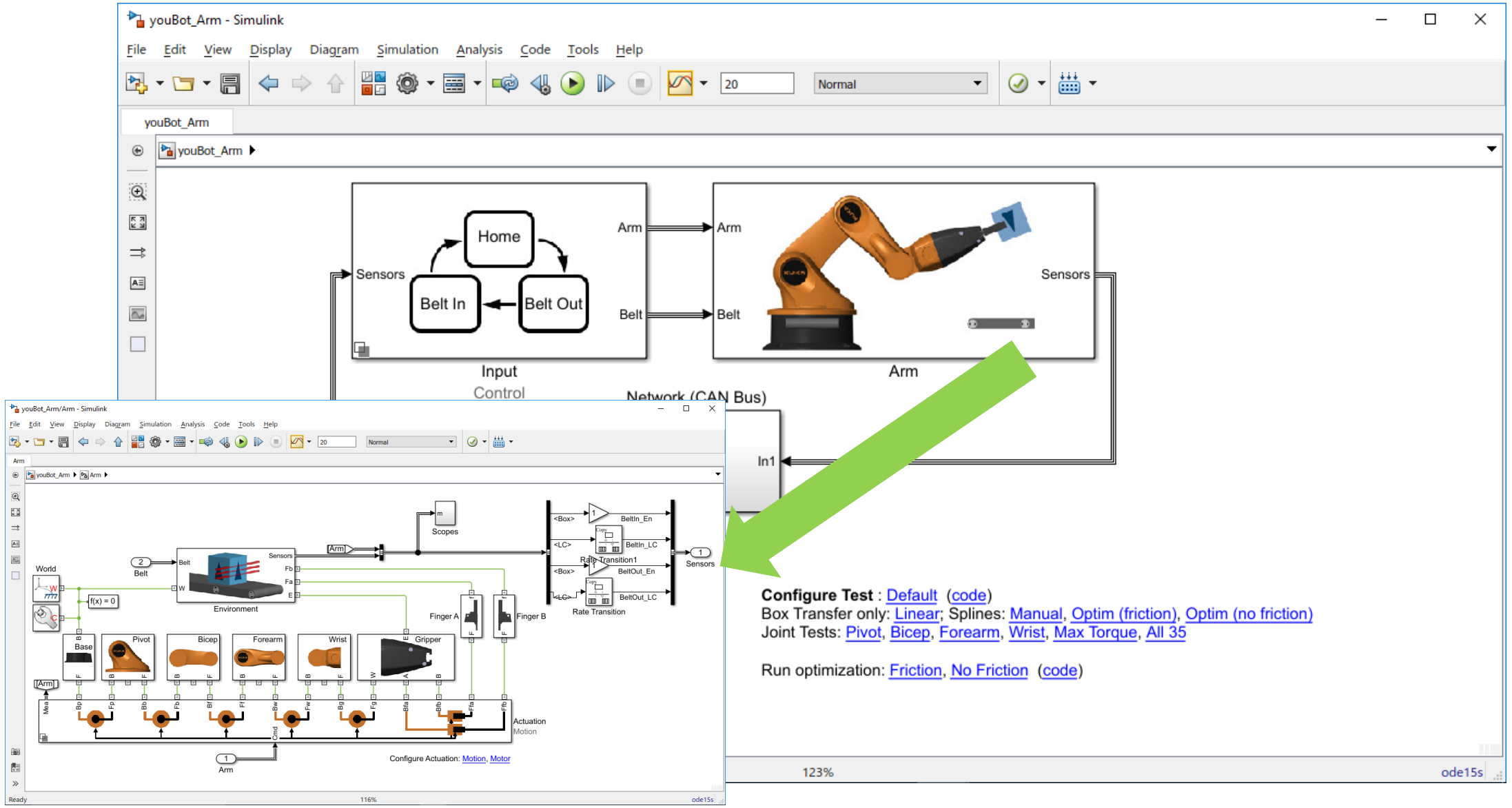
状态图和系统动态建模


youBot_Arm - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
youBot_Arm
Home
Belt In
Belt Out
Sensors
Arm
Belt
Input
Control
Out1
In1
youBot Arm
1. Plot motor currents (code) and torques (code)
2. Plot joint angles (code) and forces (code)
3. Plot box trajectory (code)
4. Explore simulation results using sscexplore
5. Plot optimization results: Friction, No Friction (code)
6. Compare optimization results (code)
7. Load model parameters (code)
8. Learn more about this example
Ready
123%
Stateflow (chart) youBot_Arm/Input/Control/Logic - Simulink
BeltIn
Empty entry:BeltIn_En = 0;
[BeltIn_Box ==1]
On entry:BeltIn_En=1;
[BeltIn_LC ==0]
BoxReady entry:Robot.GetBox BeltIn_En=0;
[BeltIn_LC==1]
WaitClear
after(delayBeltClear,sec)
Robot
StartHome entry: Way=0;
GetBox
GoBeltIn entry:Gripper.OpenGrip Way=1;
after(delayGripBox,sec)
BeltIn entry:Gripper.GripBox
MoveBox
GoBeltOut entry:Way=2;
after(delayDropBox,sec)
BeltOut entry:Gripper.DropBox
GoHome
GoingHome entry:Way=3;
after(delayClose,sec)
Home entry:Gripper.Close
Gripper
Closed entry:Grip=0;
OpenGrip
Close
Open entry:Grip=1;
GripBox
Tighten entry:Grip=2;
after(delayMoveBox,sec)
Grip entry:Robot.MoveBox
DropBox
Release entry:Grip=1;
[after(delayShipBox,sec)]
{BeltOut.ShipBox}
BeltOut
Empty entry:BeltOut_En = 0;
[BeltOut_Box==1]
WaitRelease
ShipBox
On entry:BeltOut_En=1;
[BeltOut_LC ==0]
BoxReady entry:Robot.GoHome BeltOut_En=0;
[BeltOut_LC==1]
WaitClear
after(delayBeltClear,sec)
youBot_Arm/.../Control/Joint Commands - Simulink
Way
YBT_Par.Waypoints.Home.q
Constant
Integrator
Home to BeltIn
BeltIn to BeltOut
BeltOut to Home
Unit Delay
Select Arm Trajectory
cP
cB
cF
cW
cG
bus
Grip
[1 1]*YBT_Par.Gripper.Position.closed
[1 1]*YBT_Par.Gripper.Position.open
[1 1]*YBT_Par.Gripper.Position.tight
Rate Limiter
ca
cb
Select Finger Position
Scope

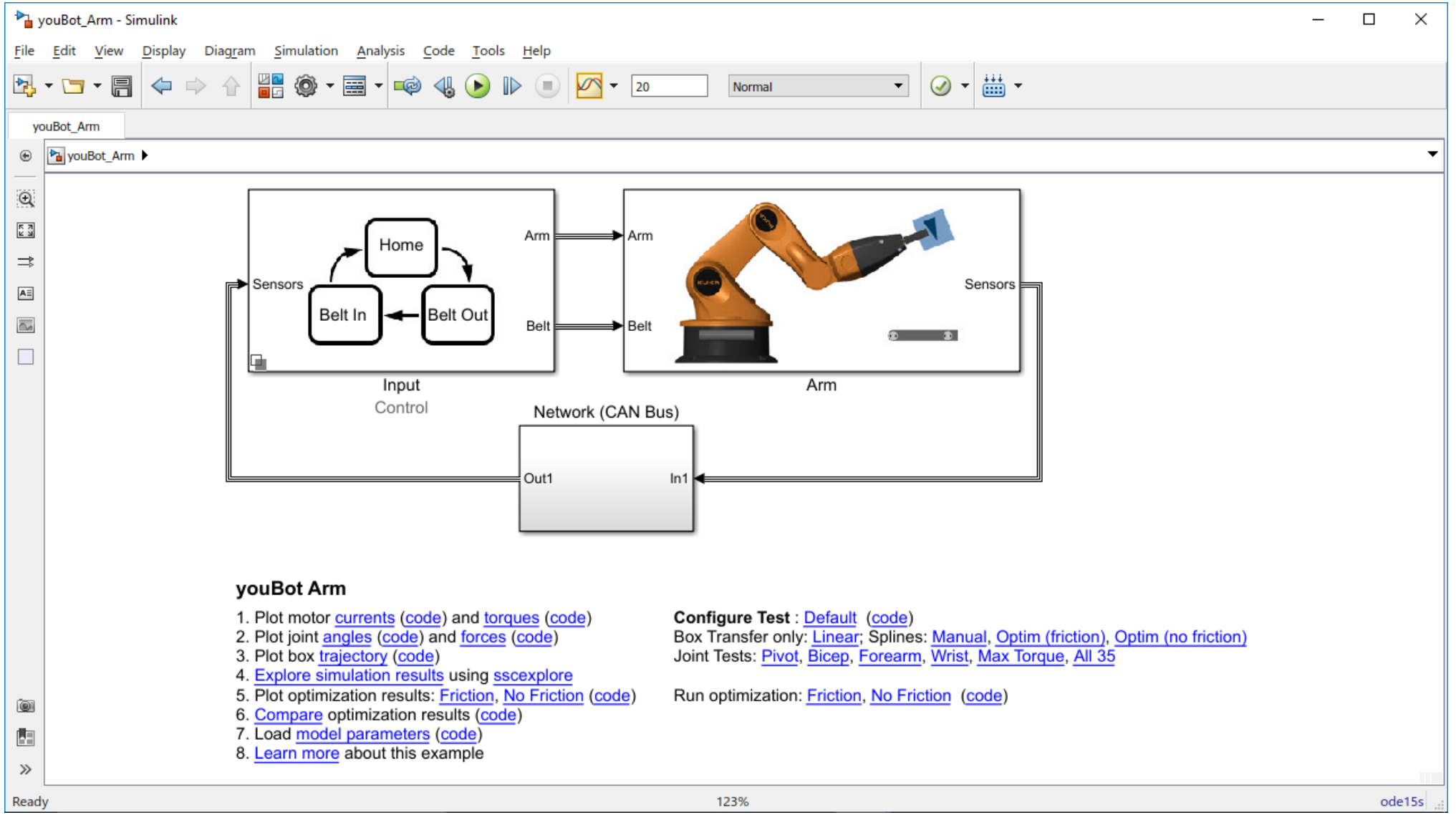
机械臂的多域模型


youBot_Arm - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
20
Normal
youBot_Arm
youBot_Arm
Home
Sensors
Belt In
Belt Out
Arm
Belt
Input
Control
Arm
Arm
Belt
Sensors
Network (CAN Bus)
Out1
In1
youBot Arm
1. Plot motor currents (code) and torques (code)
2. Plot joint angles (code) and forces (code)
3. Plot box trajectory (code)
4. Explore simulation results using sscexplore
5. Plot optimization results: Friction, No Friction (code)
6. Compare optimization results (code)
7. Load model parameters (code)
8. Learn more about this example
Configure Test : Default (code)
Box Transfer only: Linear; Splines: Manual, Optim (friction), Optim (no friction)
Joint Tests: Pivot, Bicep, Forearm, Wrist, Max Torque, All 35
Run optimization: Friction, No Friction (code)
Ready
123%
ode15s

物理系统建模


youBot_Arm - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
youBot_Arm
Home
Belt In
Belt Out
Sensors
Arm
Belt
Input
Control
Arm
Sensors
Network (CAN Bus)
In1
Configure Test : Default (code)
Box Transfer only: Linear; Splines: Manual, Optim (friction), Optim (no friction)
Joint Tests: Pivot, Bicep, Forearm, Wrist, Max Torque, All 35
Run optimization: Friction, No Friction (code)
123%
ode15s
youBot_Arm/Arm - Simulink
Scopes
Environment
Rate Transition
Rate Transition1
Finger A
Finger B
Base
Pivot
Bicep
Forearm
Wrist
Gripper
Actuation
Motion
Configure Actuation: Motion, Motor

机械臂的多域模型


youBot_Arm - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
20
Normal
youBot_Arm
youBot_Arm
Home
Sensors
Belt In
Belt Out
Arm
Belt
Input
Control
Arm
Arm
Belt
Sensors
Network (CAN Bus)
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In1
youBot Arm
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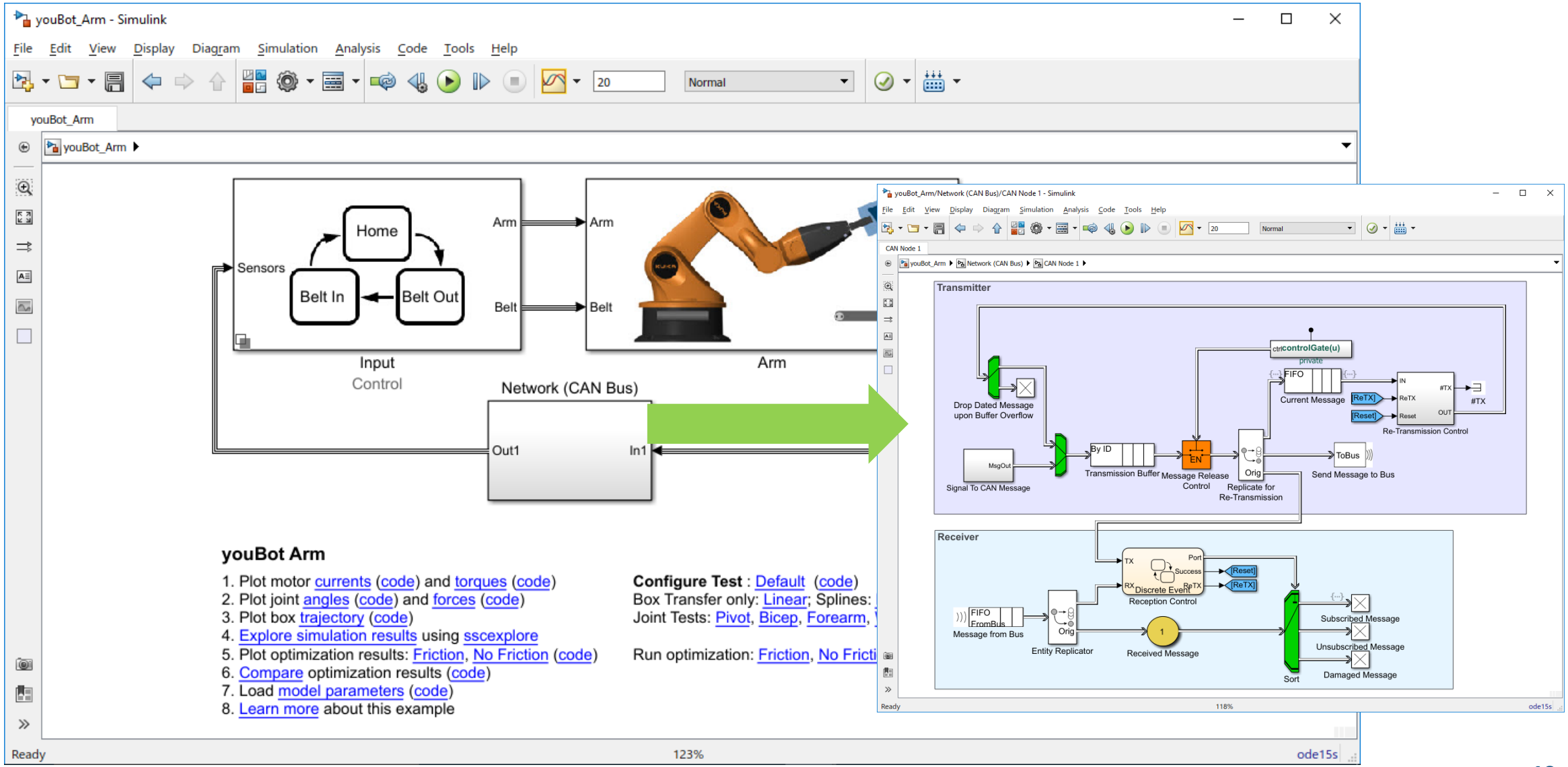
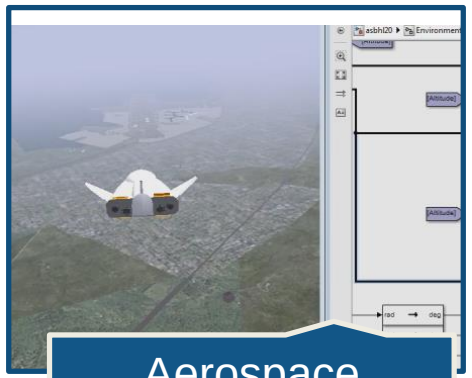
Box Transfer only: Linear; Splines: Manual, Optim (friction), Optim (no friction)
Joint Tests: Pivot, Bicep, Forearm, Wrist, Max Torque, All 35
Run optimization: Friction, No Friction (code)
Ready
123%
ode15s

离散事件建模


youBot_Arm - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
youBot_Arm
Home
Sensors
Belt In
Belt Out
Arm
Belt
Input
Control
Arm
Belt
Arm
Network (CAN Bus)
Out1
In1
youBot Arm
1. Plot motor currents (code) and torques (code)
2. Plot joint angles (code) and forces (code)
3. Plot box trajectory (code)
4. Explore simulation results using sscexplore
5. Plot optimization results: Friction, No Friction (code)
6. Compare optimization results (code)
7. Load model parameters (code)
8. Learn more about this example
Configure Test : Default (code)
Box Transfer only: Linear; Splines:
Joint Tests: Pivot, Bicep, Forearm,
Run optimization: Friction, No Fricti
Ready
123%
ode15s
youBot_Arm/Network (CAN Bus)/CAN Node 1 - Simulink
CAN Node 1
Transmitter
ctrlcontrolGate(u)
private
Drop Dated Message upon Buffer Overflow
FIFO
Current Message
ReTX
Reset
Re-Transmission Control
#TX
MsgOut
Signal To CAN Message
By ID
Transmission Buffer
EN
Message Release Control
Orig
Replicate for Re-Transmission
ToBus
Send Message to Bus
Receiver
TX
RX
Port
Success
Discrete Event
Reception Control
FIFO FromBus
Message from Bus
Orig
Entity Replicator
1
Received Message
Sort
Subscribed Message
Unsubscribed Message
Damaged Message
Ready
118%
ode15s

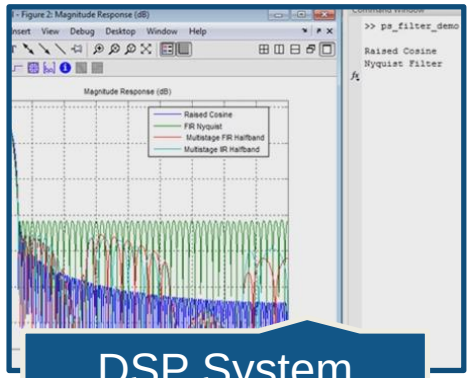
专业领域建模

Simulink提供了丰富的各专业领域建模工具

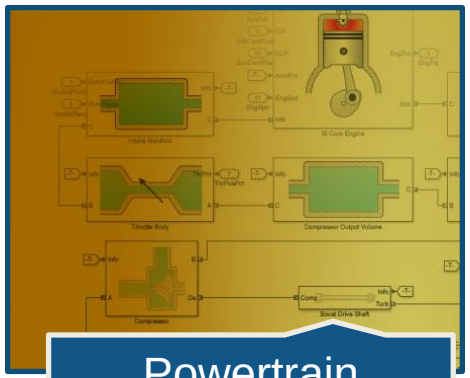


Aerospace Blockset

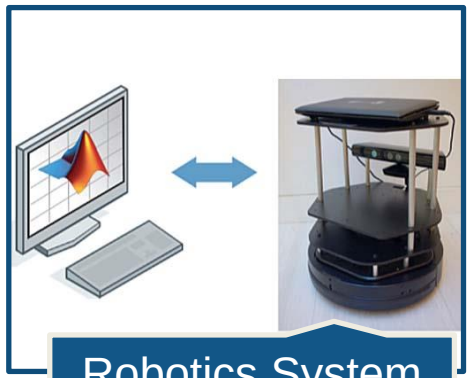
Computer Vision System Toolbox



DSP System Toolbox

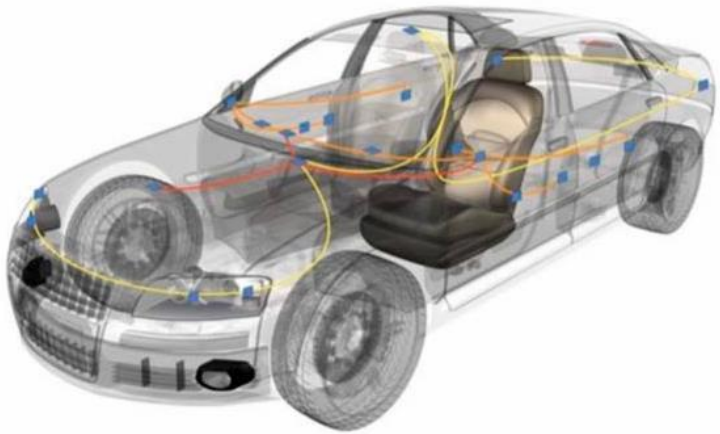


Powertrain Blockset

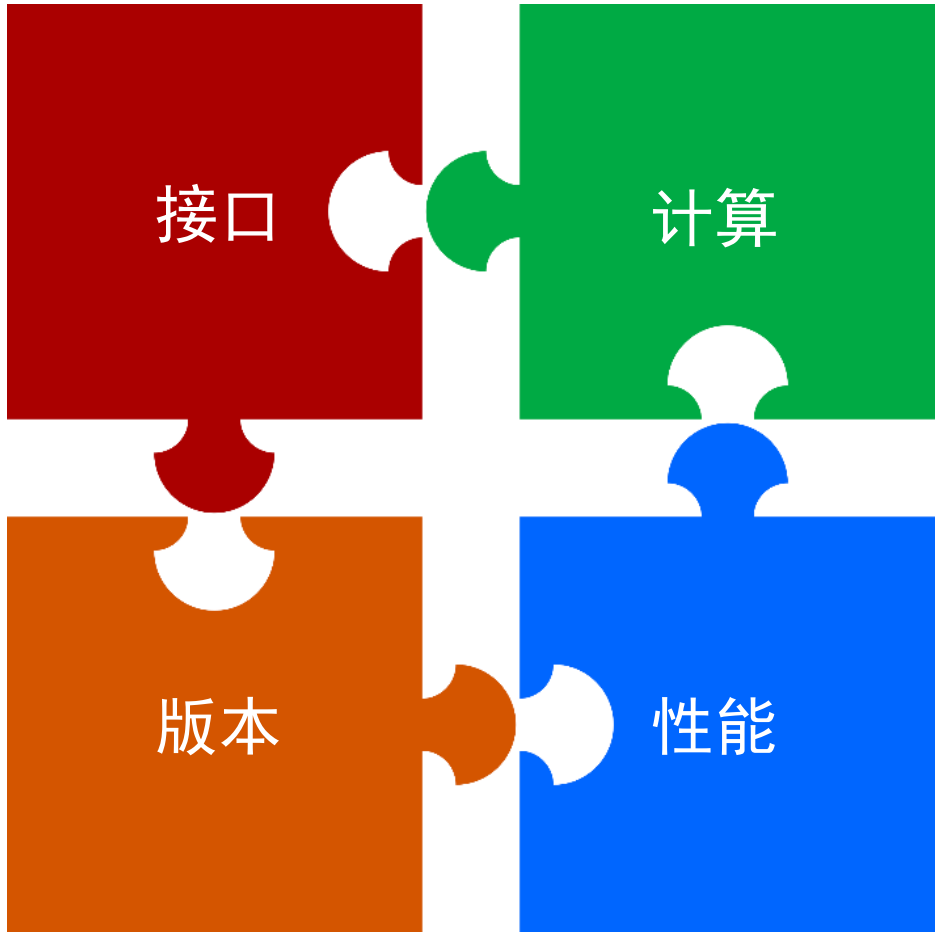


Robotics System Toolbox

仿真集成



充分利用企业的模型资产

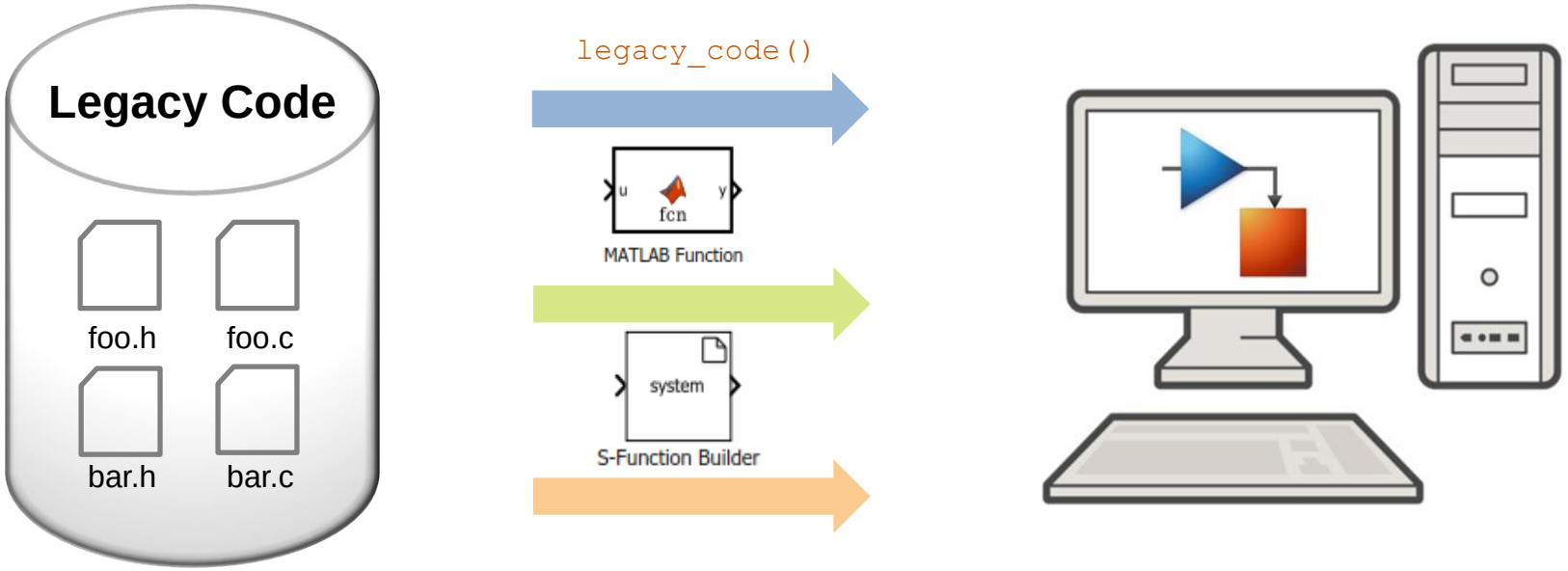


基于S-function的集成

- 被行业多次证明可行的解决方案
  - 二十余年的支持
  - 提供了丰富的 API
  - 良好的向下版本兼容性
- 许多工具支持导出S-function功能
- 提供C代码集成工具
  - Legacy Code Tool
  - S-function Builder

应用 – 代码集成

多种方式重用已有代码

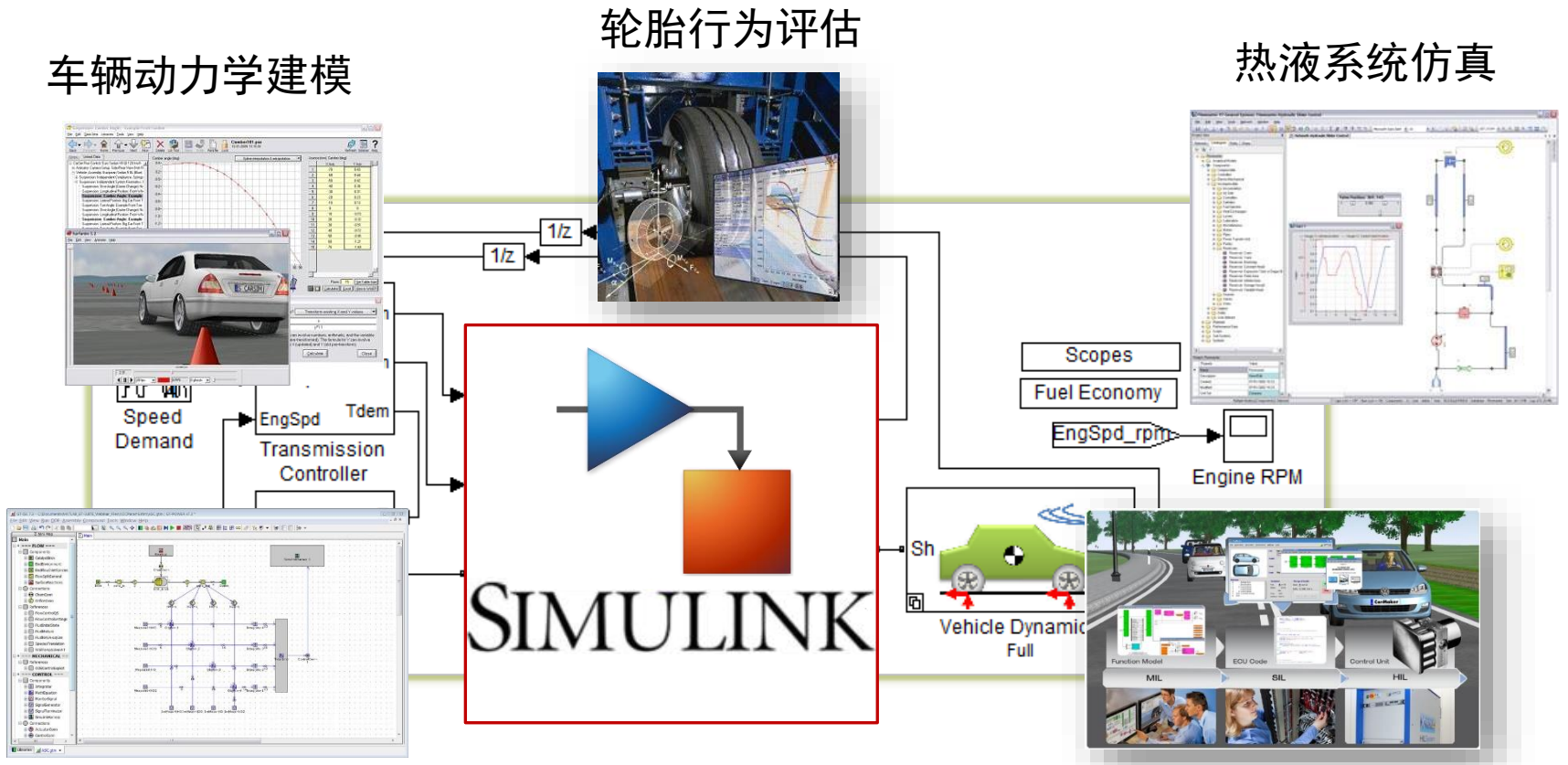


应用 – 第三方工具集成

车辆动力学建模

轮胎行为评估

热液系统仿真

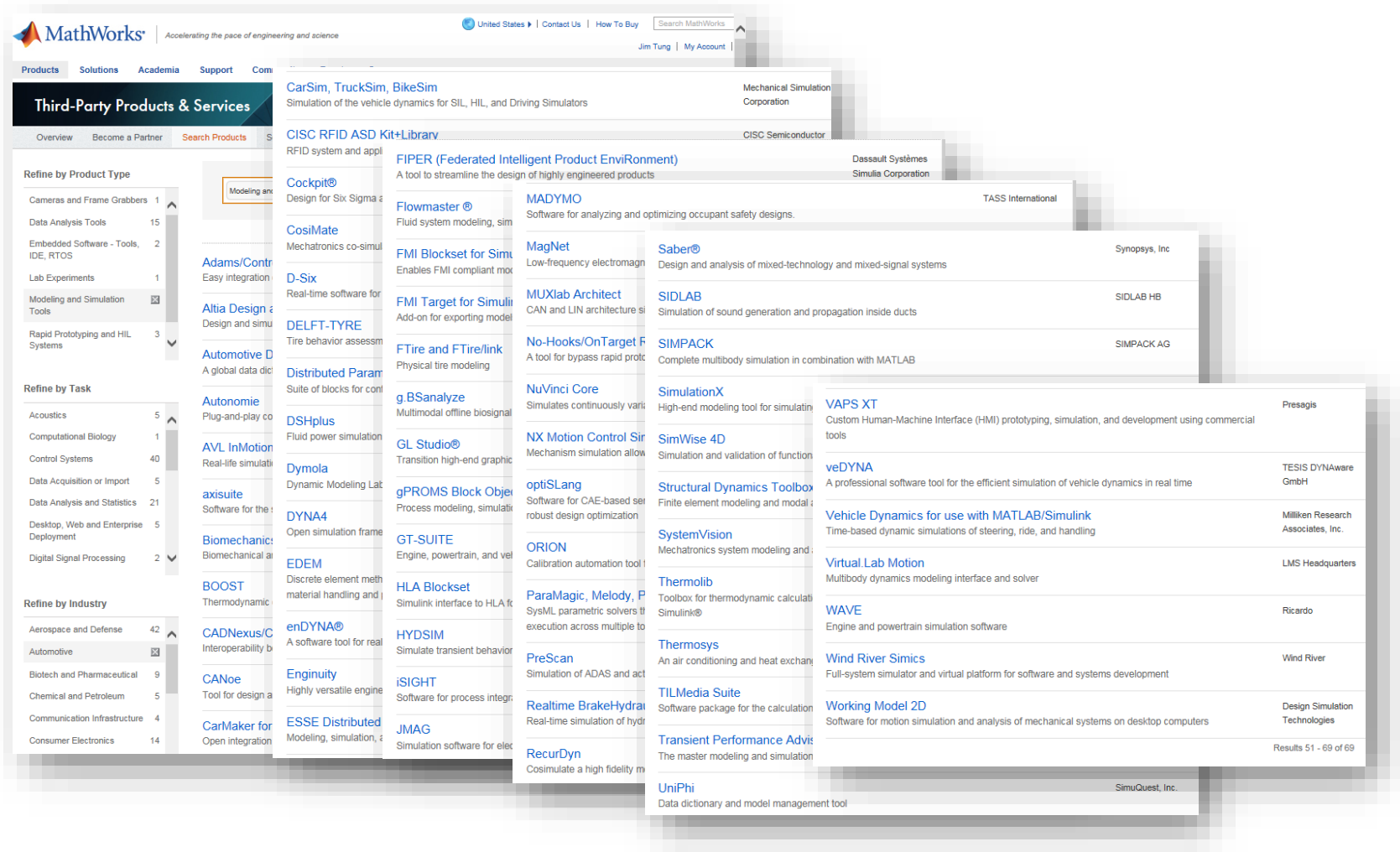


1D / 3D 发动机/排放仿真

虚拟驾驶测试

基于S-function集成的优势

成熟而丰富的合作伙伴生态系统



基于FMI的仿真集成

- 2010年发布了1.0版, 2014年发布了2.0版
- Simulink自R2017b版起内嵌支持FMU导入功能
- Simulink自R2019a版起支持FMU导出功能

Solver	Import/Master Simulation Integration Platform	Export/Slave Component Authoring
Variable Step	✓ R2017b	
Fixed Step	✓ R2017b	

第三方的FMI解决方案

Third-Party Products & Services

Overview | Become a Partner | Search Products | Search S

FMI Target for Simulink Coder

Add-on for exporting models from MATLAB and Simuli

Highlights

- Serves as a cross-platform solution
- Exports models from MATLAB and Simulink as functional m
- Exports FMUs that include the MATLAB and Simulink solve
- Supports FMI 1.0

Description

The FMI Target for Simulink Coder™ enables you to export mo from Simulink® as functional mock-up units (FMUs) for cosimulation and use across a variety of platforms. This allows a continuous workflow in a complete toolchain throughout the product lifecycle.

With this add-on, you can export models from MATLAB® and Simulink as FMUs that are fully FMI 1.0 compliant and include models' functionality. Models can also include a Simulink solve that enables any tool supporting FMUs for cosimulation to run unit.

Supporting your vision

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01067 Dresden
Tel: +49-351-26050-200
Fax: +49-351-26050-155
info@itisim.com
www.itisim.com

Related Connections Views: Modeling and Simulation Tools, C Modeling and Simulation, Automotive

Third-Party Products & Services

Overview | Become a Partner | Search Products | Search S

FMI Blockset for Simulink

Enables FMI compliant models to be imported and run

Highlights

- Supports the FMI open standard for cosimulation
- Import models from over 30 tools into Simulink
- Configure the models in Simulink with an intuitive interface

Description

The FMI Blockset for Simulink provides support for the FMI ope standard for cosimulation. Users can import models that follow FMI open standard (Functional Mockup Units, or FMUs) into Simulink® for cosimulation.

The FMI Blockset for Simulink contains blocks that handle the communication between Simulink and the FMI compliant mode Each version of FMI is supported by a separate block. There is graphical interface that allows the user to select and configure FMU within the Simulink model. The interface supports the loa and configuration of the model for cosimulation. It also provides access to the model parameters, and it includes support for converting units and linking parameters to the MATLAB® workspace.

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Fax: +44-1926-885910
info@claytex.com
www.claytex.com

Third-Party Products & Services

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FMI Toolbox

Command line interface and blockset for integrating FMI-compliant model units into MATLAB and Simulink

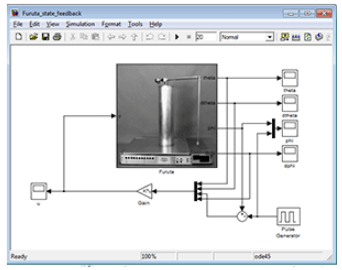
Highlights

- Model exchange with more than 35 different software tools
- Import/export and simulation of FMUs in Simulink
- Import and simulation of FMUs in MATLAB scripts
- Support for co-simulation and model-exchange FMUs
- FMI open standard version 1.0 fully supported
- FMI standard version 2.0 supported for Simulink FMU import

Description

FMI Toolbox enables integration and exchange of models developed in a variety of modeling tools into the MATLAB® and Simulink® environments using the open standard functional mock-up interface (FMI) format.

FMI Toolbox offers user functions to load and access FMUs from command line and scripts, as well as a blockset for using FMUs in Simulink, and the capability to export Simulink models as FMUs. FMI Toolbox enables the use of MATLAB and Simulink as integration platforms in heterogeneous engineering tool environments. The toolbox is used for batch simulation processing, design of experiments, control design, as well as validation and verification analysis. The FMI Toolbox offers an intuitive workflow to combine physical models on a system level in an efficient manner.



Enlarge
Simulink model containing an FMU and a simple control system developed using Simulink blocks

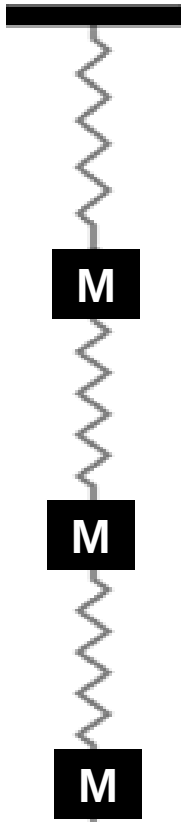
FMI was pioneered by OEMs in the automotive industry, and is now an established technology in all systems industries. The FMI technology is supported by a large number of open source and commercial software tools for systems engineering. See fmi-standard.org for more information.

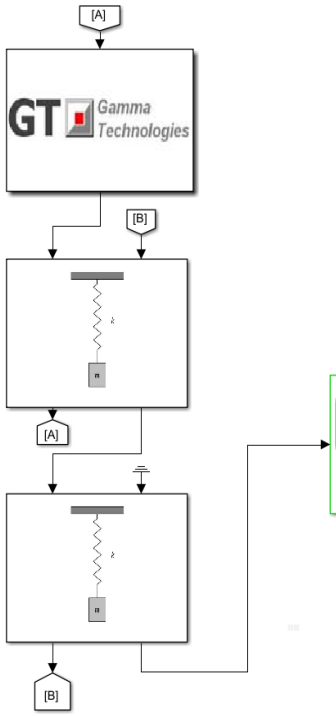
Modelon AB

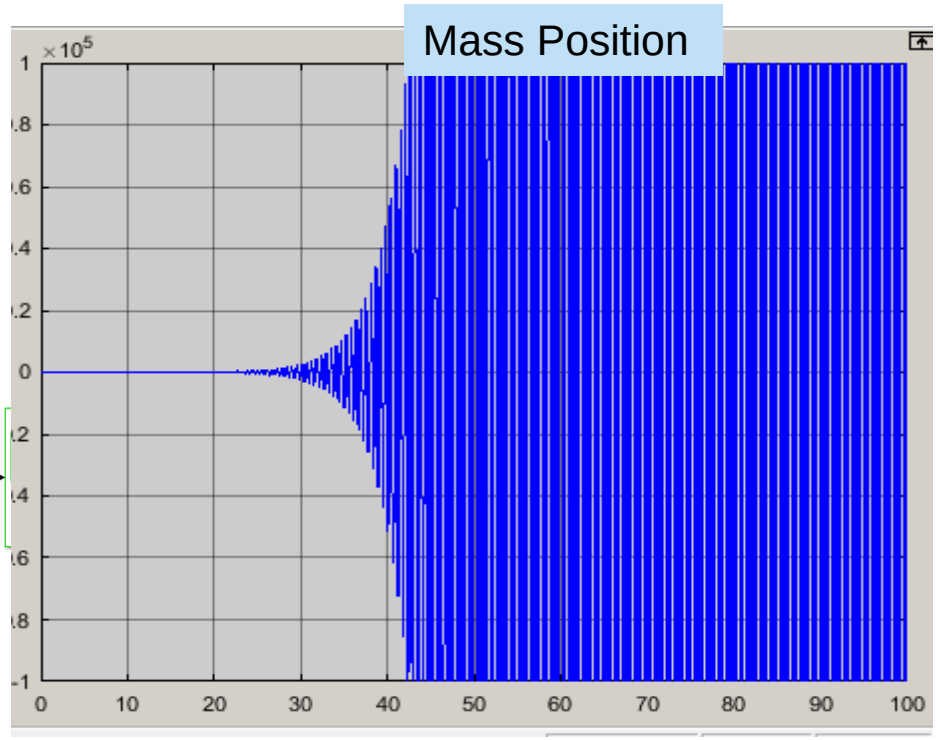
Ideon Science Park
LUND, 223 70
SWEDEN
Tel: +46-462-862204
Fax: +46-462-862201
info@modelon.com
www.modelon.com

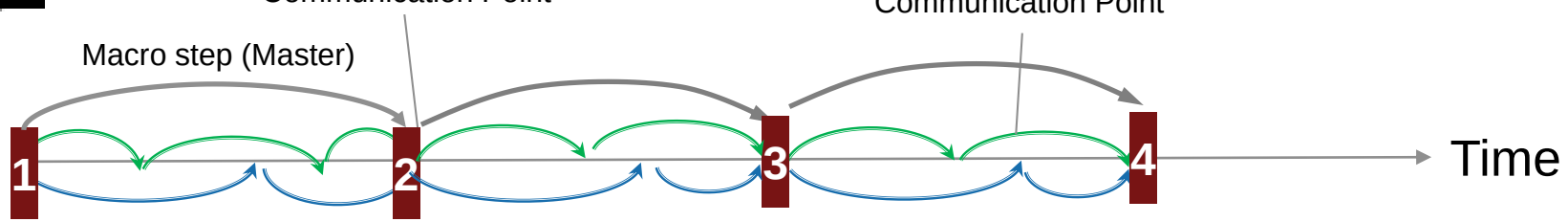
联合仿真的失真问题

零阶保持器在联合仿真边界的数据交换导致仿真失真



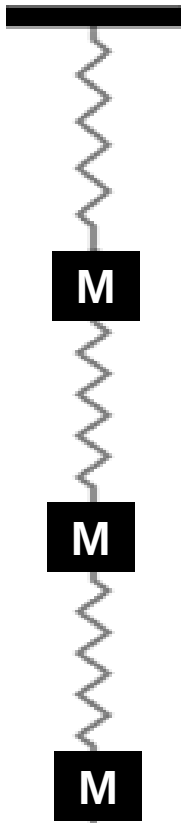


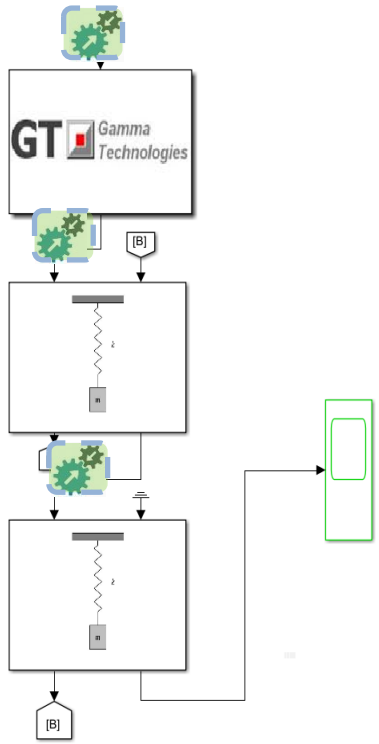


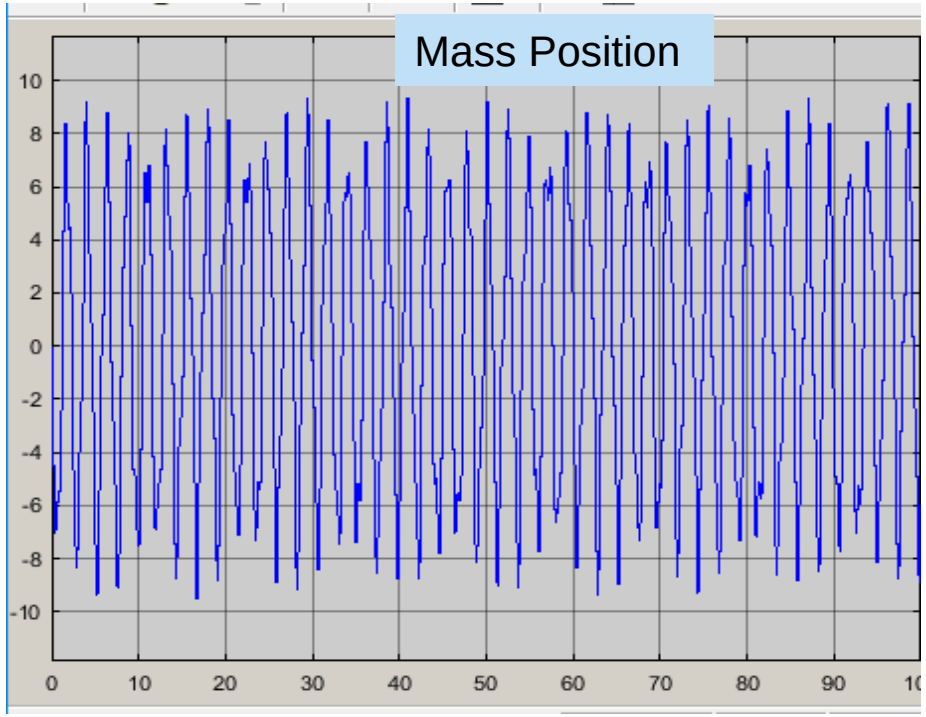


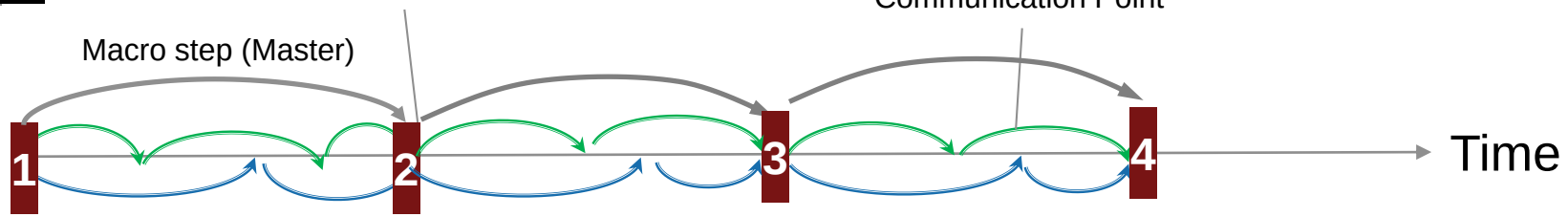
联合仿真的数值补偿功能

在联合仿真中Simulink可以自动进行数值补偿，以避免仿真失真

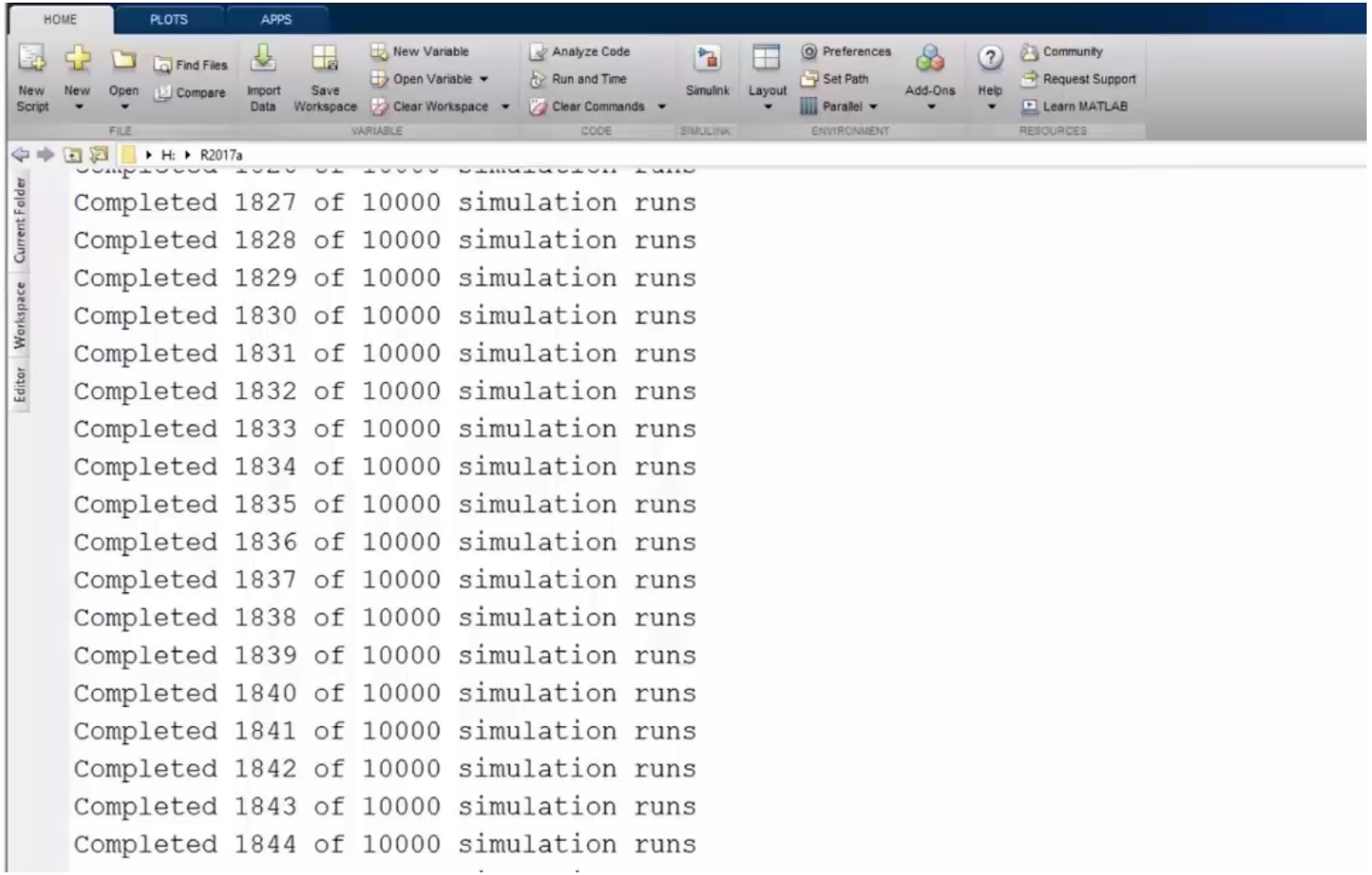








并行仿真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Compare
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
Analyze Code
Run and Time
Clear Commands
Simulink
Layout
Preferences
Set Path
Parallel
Add-Ons
Help
Community
Request Support
Learn MATLAB
FILE
VARIABLE
CODE
SIMULINK
ENVIRONMENT
RESOURCES
H: ▸ R2017a
Current Folder
Workspace
Editor
Completed 1827 of 10000 simulation runs
Completed 1828 of 10000 simulation runs
Completed 1829 of 10000 simulation runs
Completed 1830 of 10000 simulation runs
Completed 1831 of 10000 simulation runs
Completed 1832 of 10000 simulation runs
Completed 1833 of 10000 simulation runs
Completed 1834 of 10000 simulation runs
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Completed 1838 of 10000 simulation runs
Completed 1839 of 10000 simulation runs
Completed 1840 of 10000 simulation runs
Completed 1841 of 10000 simulation runs
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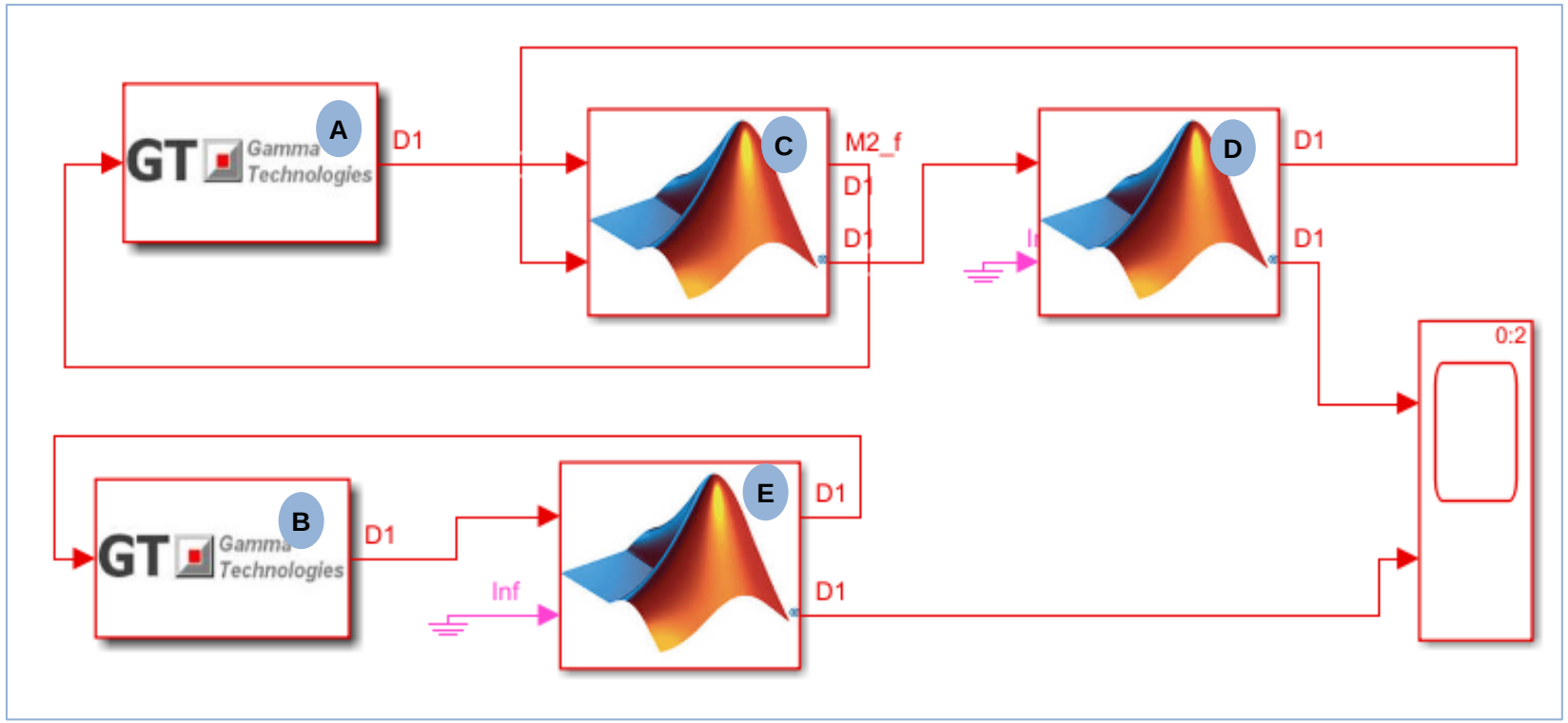
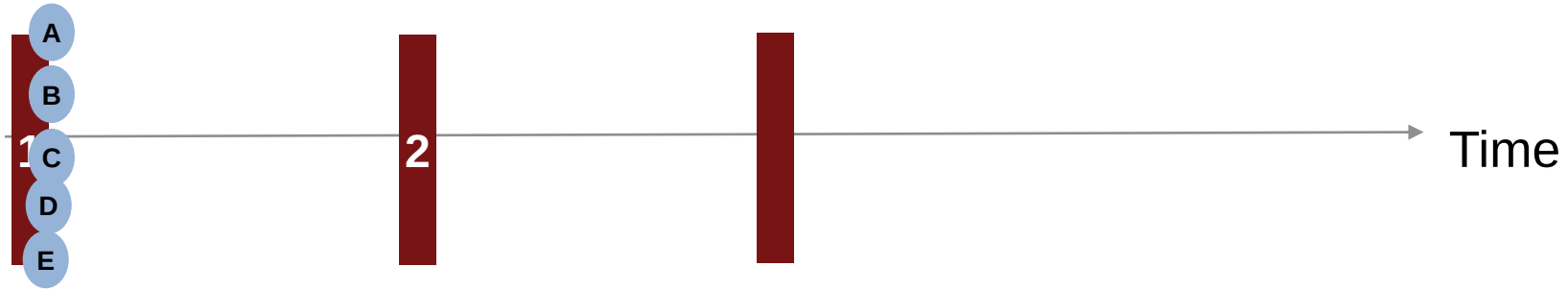
Completed 1843 of 10000 simulation runs
Completed 1844 of 10000 simulation runs

多线程联合仿真

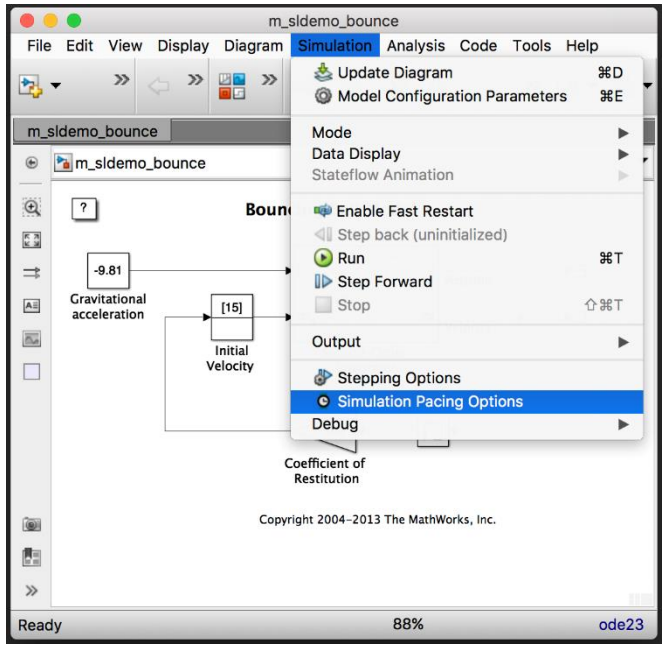


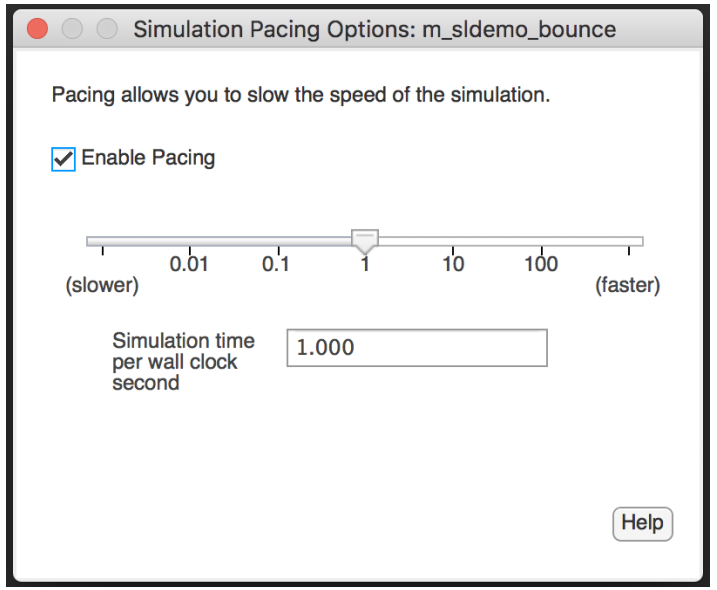


Parallel execution
Simulation time: 73 sec

Simulink Today (Sequential)
Simulation time: 123 sec

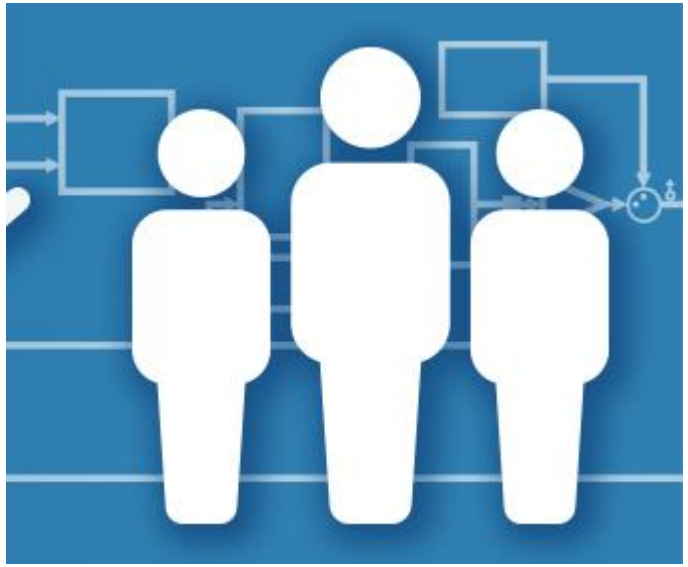
仿真调速





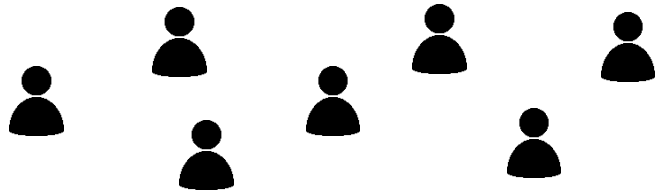
- Slow down a running simulation for easier:
  - Interaction with hardware
  - Demos
  - Control with HMI widgets

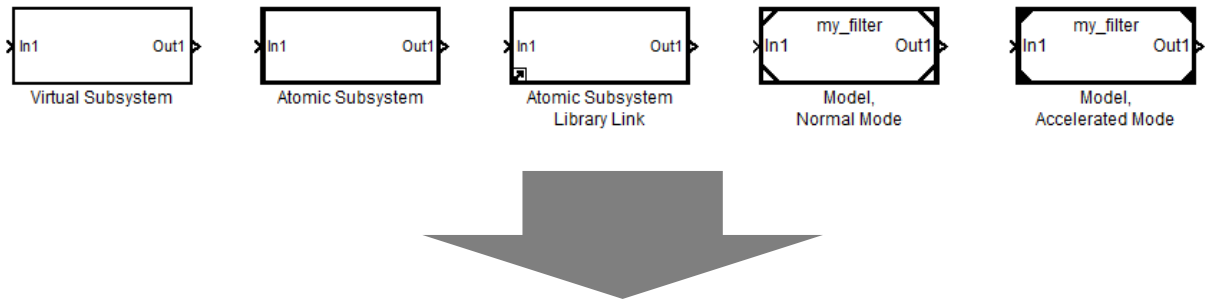
协同设计

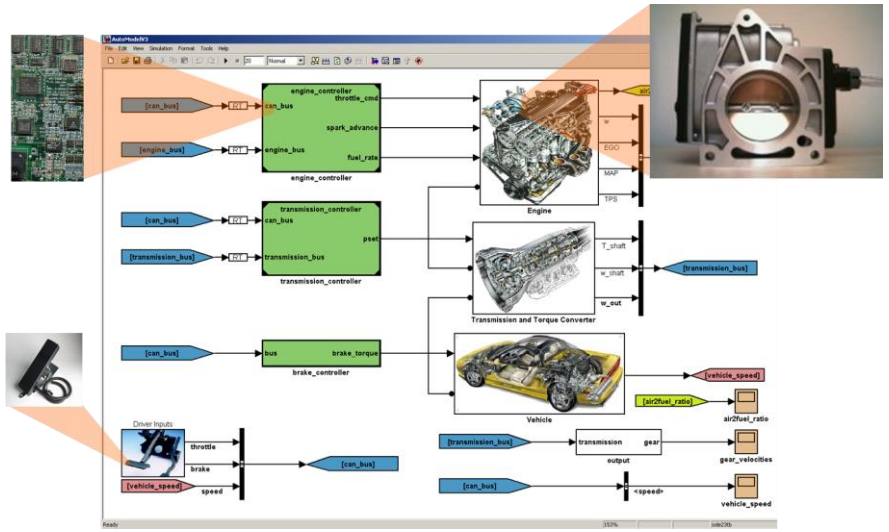


组件式开发实现复杂系统协同设计

- Simulink支持组件式协同开发流程
  - 更快的模块化开发
  - 更有效的验证
  - 提升重用性

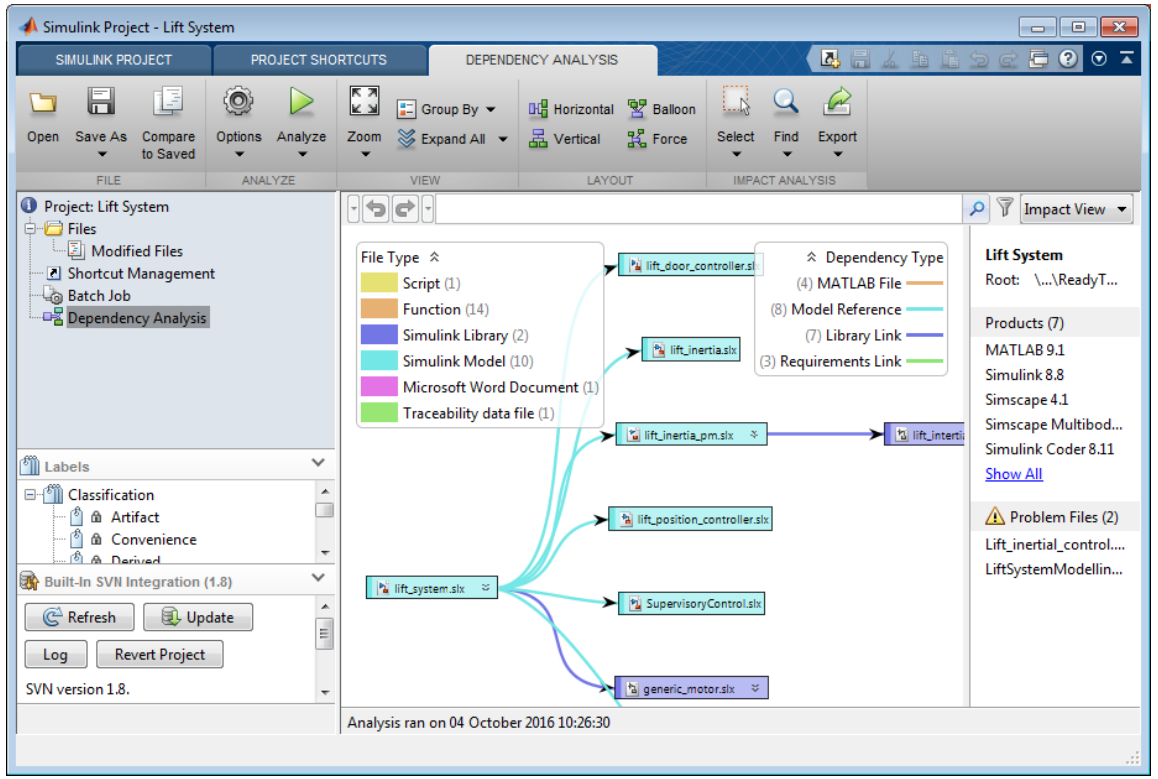






基于团队的工作流程支持

- 版本控制
- 设计比较与合并
- 依赖性分析
- 任务自动化



支持多种版本控制工具集成

Microsoft Team Foundation Server (TFS) integration available now from MathWorks File Exchange

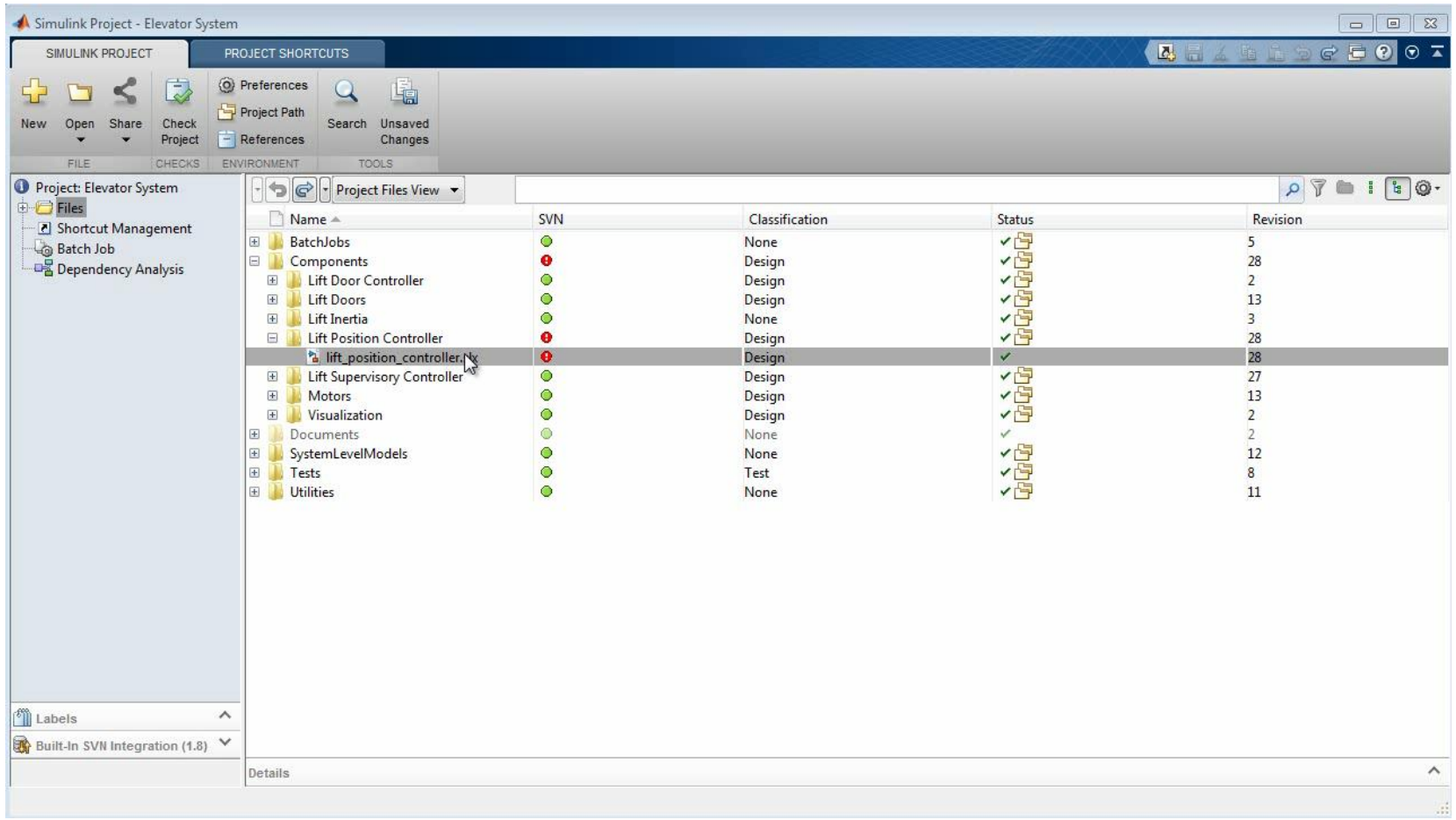
SUBVERSION

PERFORCE
Version everything.

git

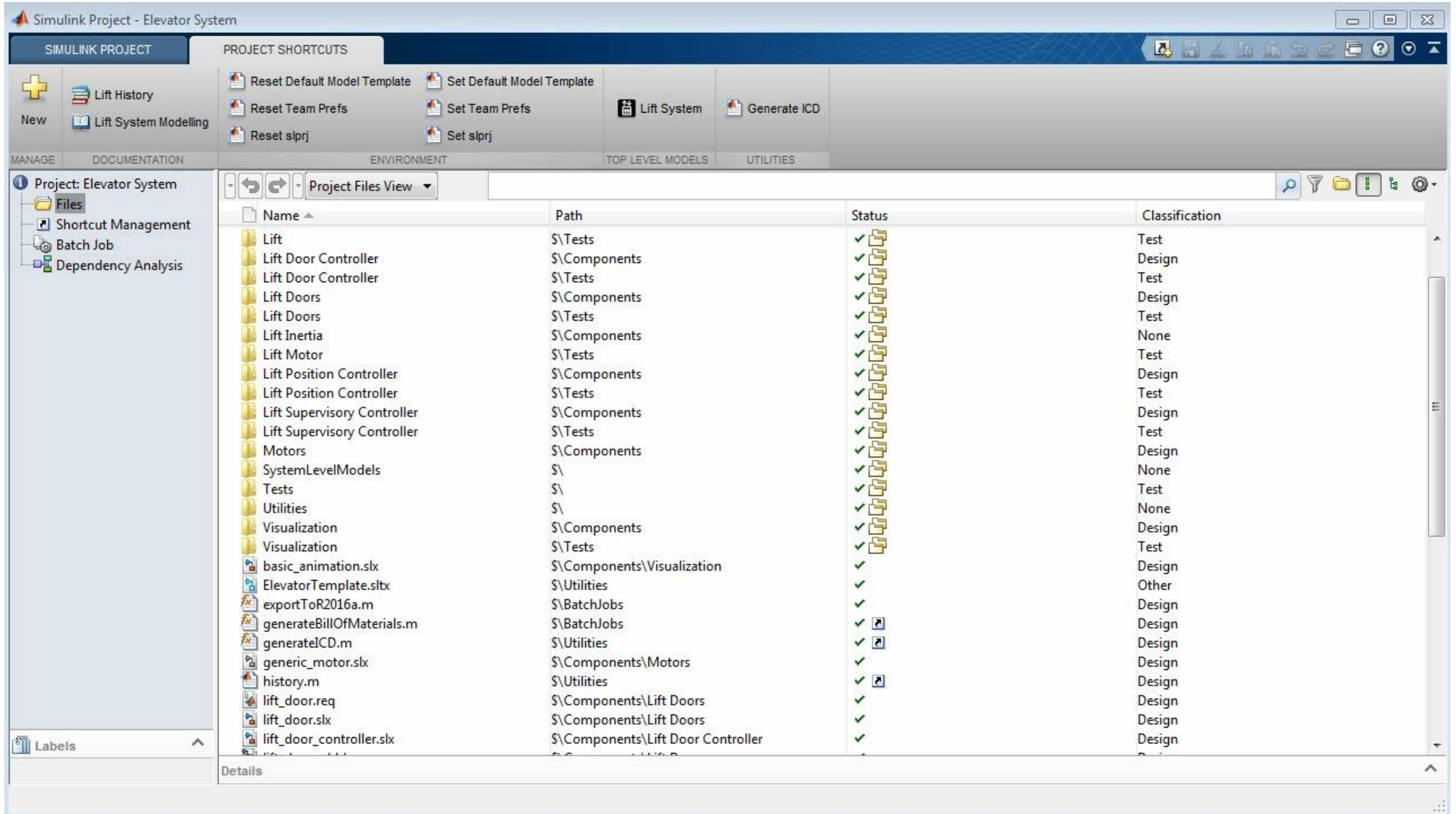
Team Foundation Server 2012
Microsoft

设计合并

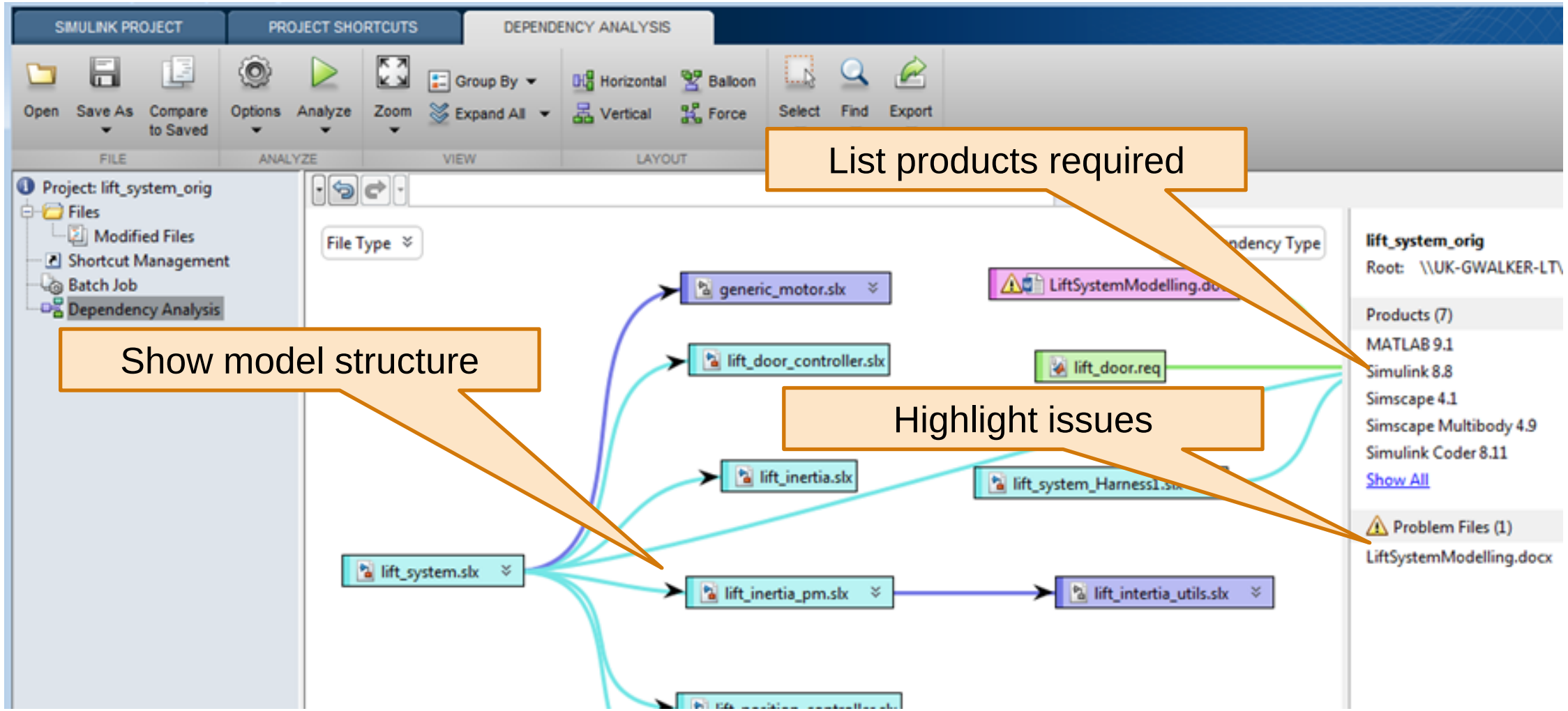


- 支持并行工程
- 可以专注于设计

依赖性分析


Simulink Project - Elevator System
SIMULINK PROJECT
PROJECT SHORTCUTS
New
Lift History
Lift System Modelling
Reset Default Model Template
Reset Team Prefs
Reset slprj
Set Default Model Template
Set Team Prefs
Set slprj
Lift System
Generate ICD
MANAGE
DOCUMENTATION
ENVIRONMENT
TOP LEVEL MODELS
UTILITIES
Project: Elevator System
Files
Shortcut Management
Batch Job
Dependency Analysis
Project Files View
Name
Path
Status
Classification
Lift $\Tests Test
Lift Door Controller $\Components Design
Lift Door Controller $\Tests Test
Lift Doors $\Components Design
Lift Doors $\Tests Test
Lift Inertia $\Components None
Lift Motor $\Tests Test
Lift Position Controller $\Components Design
Lift Position Controller $\Tests Test
Lift Supervisory Controller $\Components Design
Lift Supervisory Controller $\Tests Test
Motors $\Components Design
SystemLevelModels $\ None
Tests $\ Test
Utilities $\ None
Visualization $\Components Design
Visualization $\Tests Test
basic_animation.slx $\Components\Visualization Design
ElevatorTemplate.sltx $\Utilities Other
exportToR2016a.m $\BatchJobs Design
generateBillOfMaterials.m $\BatchJobs Design
generateICD.m $\Utilities Design
generic_motor.slx $\Components\Motors Design
history.m $\Utilities Design
lift_door.req $\Components\Lift Doors Design
lift_door.slx $\Components\Lift Doors Design
lift_door_controller.slx $\Components\Lift Door Controller Design
Labels
Details

依赖性分析


SIMULINK PROJECT
PROJECT SHORTCUTS
DEPENDENCY ANALYSIS
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Save As
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Options
Analyze
Zoom
Group By
Expand All
Horizontal
Vertical
Balloon
Force
Select
Find
Export
FILE
ANALYZE
VIEW
LAYOUT
Project: lift_system_orig
Files
Modified Files
Shortcut Management
Batch Job
Dependency Analysis
File Type
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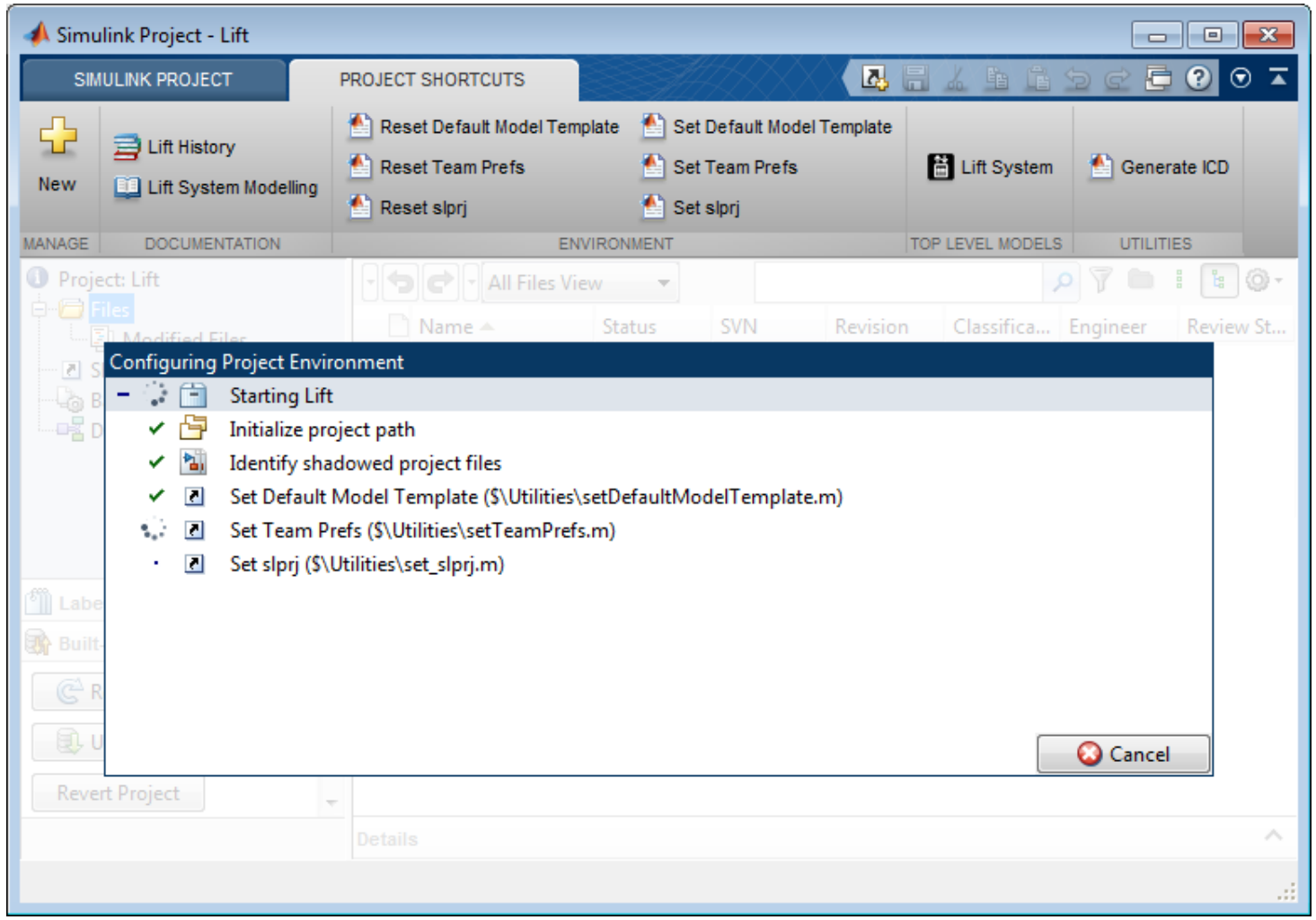
lift_door_controller.slx
lift_inertia.slx
lift_system.slx
lift_inertia_pm.slx
lift_intertia_utils.slx
lift_door.req
lift_system_orig
Products (7)
MATLAB 9.1
Simulink 8.8
Simscape 4.1
Simscape Multibody 4.9
Simulink Coder 8.11
Show All
Problem Files (1)
LiftSystemModelling.docx
List products required
Show model structure
Highlight issues

任务自动化

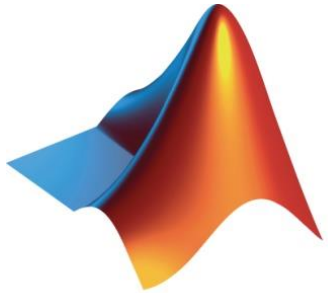


- Robustly configure the team environment
- For everyone
- Automatically

企业仿真平台总结

"*There is no such tool, which gives the simulation environment as well as the hardware verification and validation. In a single environment, I am getting these together.* ***That is why I use MATLAB and Simulink.***"

Dr. Deepak Mishra,
Indian Space Research Organization



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