

MATLAB EXPO

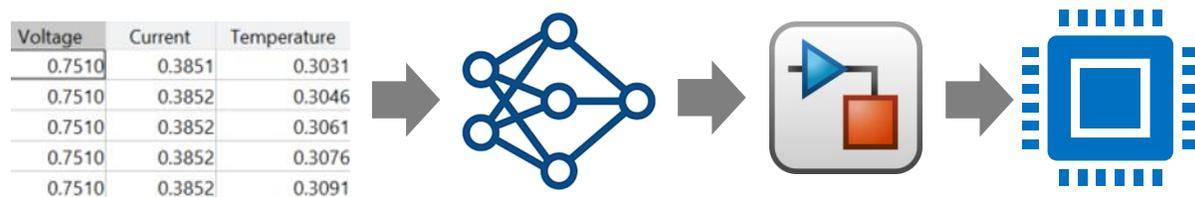
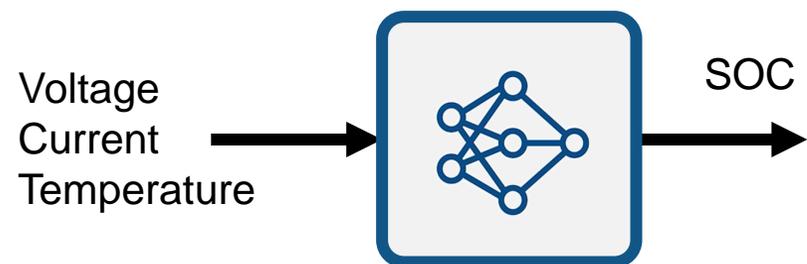
人工智能与基于模型设计在电池容量评估中的应用

马文辉, MathWorks



主要内容

- 基于AI的SOC估计方法
- 将SOC估计的AI模型引入到基于模型设计（MBD）
- MATLAB与Simulink联合仿真测试

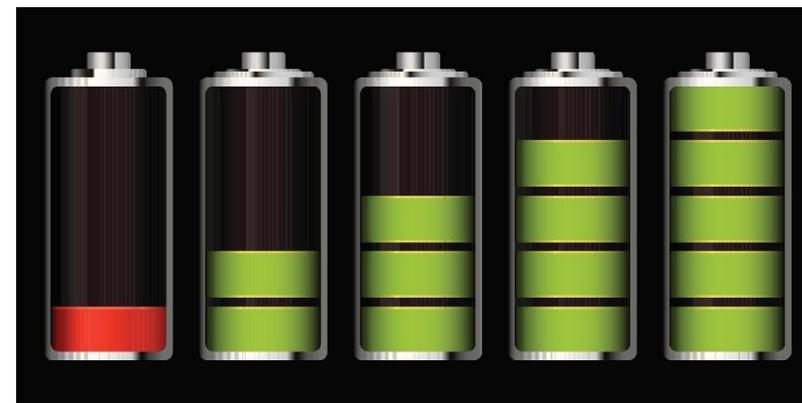


电池荷电状态 (State of Charge, SOC)

电池荷电状态 (State Of Charge, SOC) 是一个表征电池系统可靠性的重要属性。对于单体电池, SOC可以表示为可用荷电量与额定荷电量之间的比率:

$$SOC = \frac{C_a}{C_n}$$

其中, C_a 表示当前可用电荷量, C_n 表示额定电荷量。

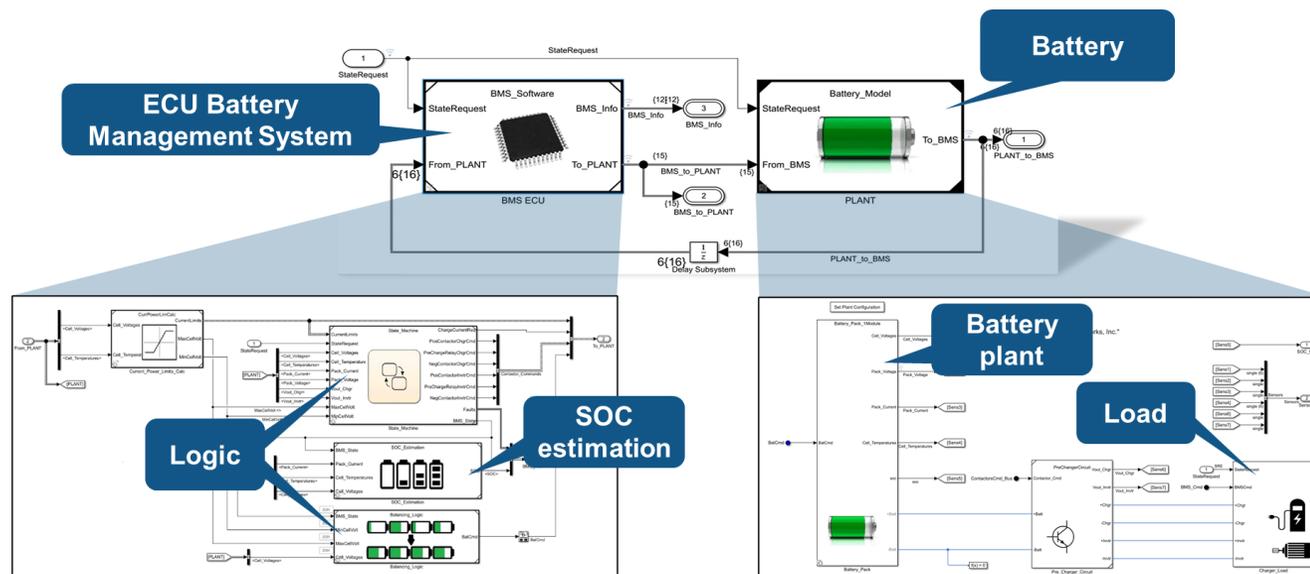


SOC

SOC估计

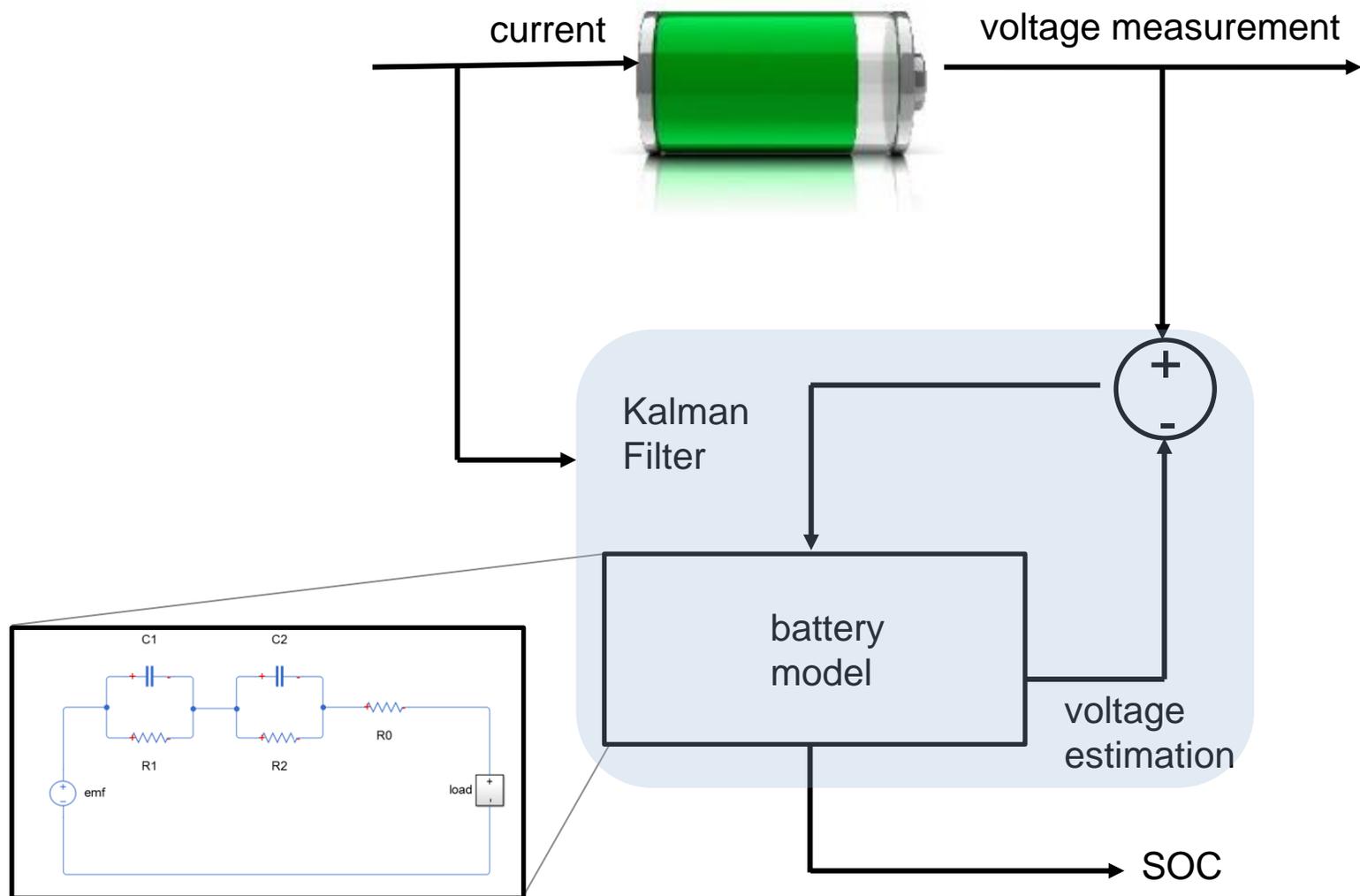
SOC 估计作为电池管理系统（BMS）的核心功能之一。准确的SOC 估计结果能够在电池寿命、安全可靠性和利用率等方面对电源管理系统提供有效的支持。

- 电池的SOC无法直接测量
- 采用间接方法测量SOC
 - 扩展的卡尔曼滤波
 - 数据驱动的方法



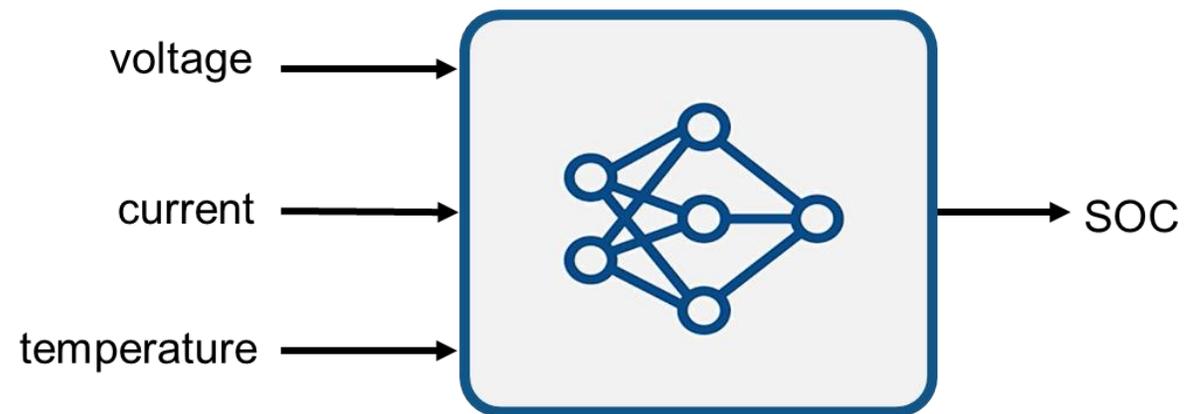
Battery State of Charge (SOC)

- SOC估计 -扩展的卡尔曼滤波
 1. 需要构建详细的电池模型
 2. 需要较大的计算量
 3. 面对复杂系统难以建模
 4. 准确性较低



Battery State of Charge (SOC)

- SOC估计 –数据驱动的方法
 1. 基于历史运行数据训练AI模型（机器学习或深度学习模型）
 2. 不需要考虑电池建模
 3. AI模型的离线训练，在线预测，响应速度快
 4. 可以应该各种复杂系统
 5. 需要获取大量的电池运行数据
 6. 黑盒模型，缺乏可解释性



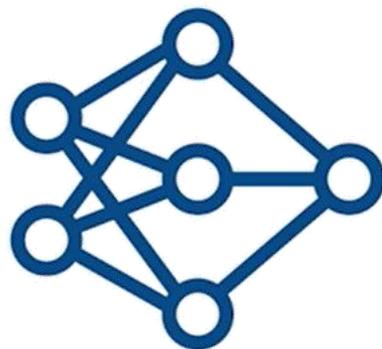
AI与基于模型设计(MBD)集成开发的流程

利用MATLAB和Simulink，可以将AI算法应用于模型设计中

数据预处理

Voltage	Current	Temperature
0.7510	0.3851	0.3031
0.7510	0.3852	0.3046
0.7510	0.3852	0.3061
0.7510	0.3852	0.3076
0.7510	0.3852	0.3091

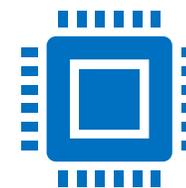
AI建模



仿真测试



集成部署



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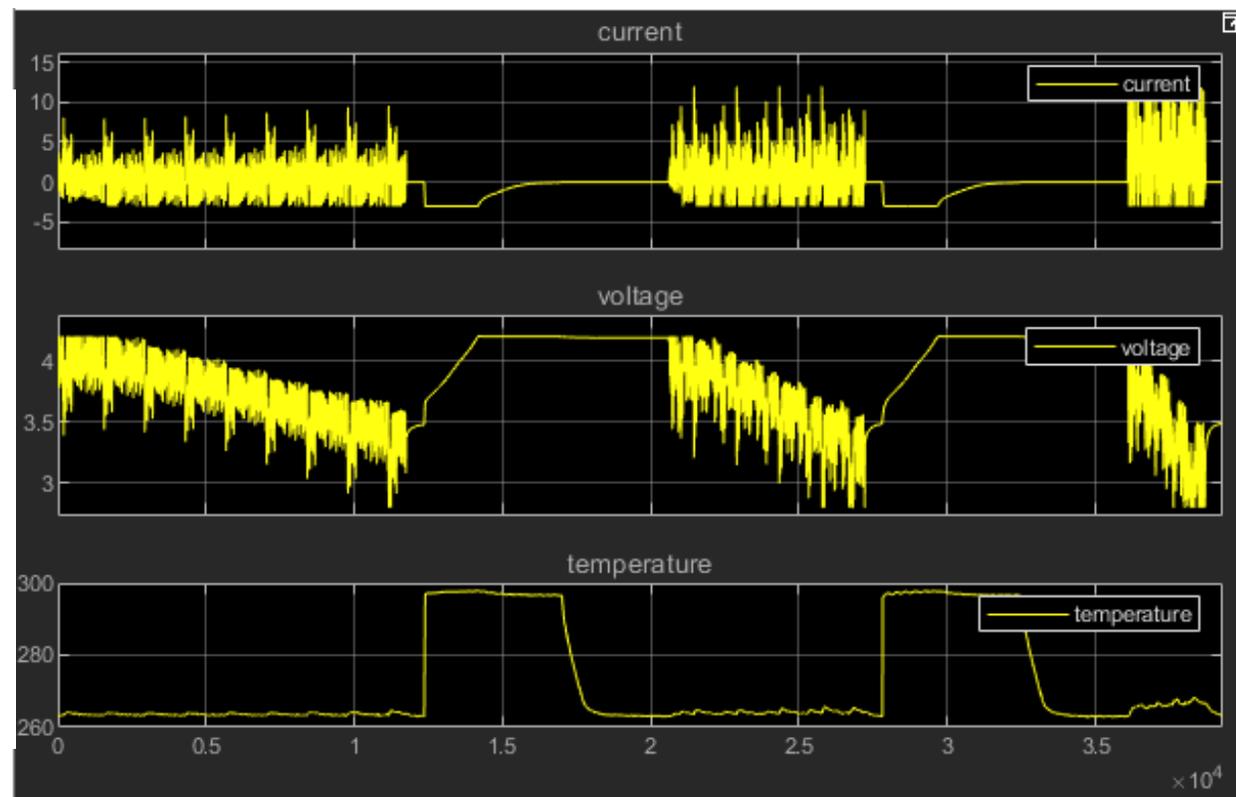
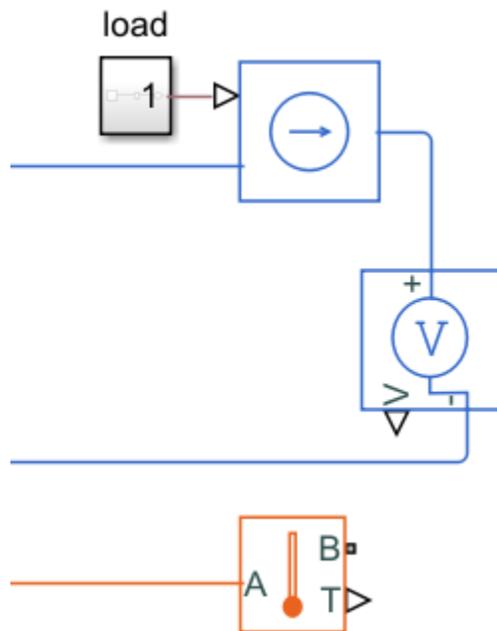


数据获取

- 运行数据，通过传感器采集
- 实验室数据
- 仿真数据，故障仿真，衰退仿真

特征提取、衍生

- 时域特征
- 频域特征



AI建模模型

机器学习模型和深度学习模型

Logistic Regression
 Naive Bayes Nonlinear
Nearest Neighbors
 Stepwise SVM Boosting
Random Forrest
 Discriminant Analysis
 GP Regression

传统机器学习模型

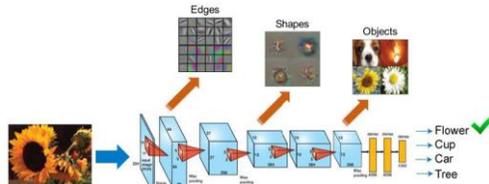
EfficientNet-b0
 NASNet-Mobile
 Inception-v3 **VGG-19** DenseNet-201
EfficientNet-b0
ShuffleNet
Squeezenet
 ResNet-101 **VGG-16**
 GoogLeNet DarkNet-53
 MobileNet-v2

迁移学习模型

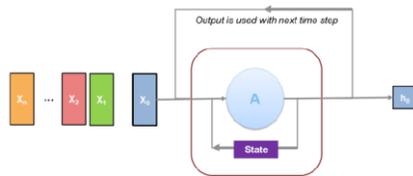
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CNN (Convolutional)



LSTM (Recurrent)



- dlarray** 数据容器（输入、中间计算、输出）
- dlnetwork** 网络容器
- dlfeval** 评估深度学习模型或功能
- dlgradient** 使用自动微分（autodiff）计算梯度
- dlupdate*** 使用求解器执行一步反向传播

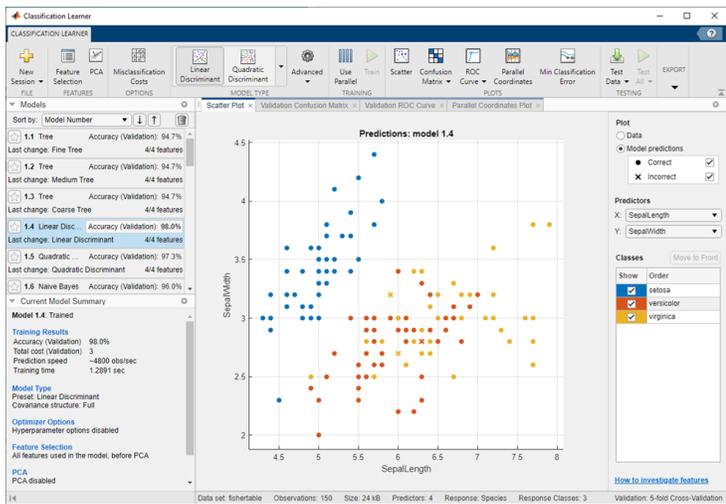
自定义深度神经网络模型及训练过程

AI 模型构建、训练与验证

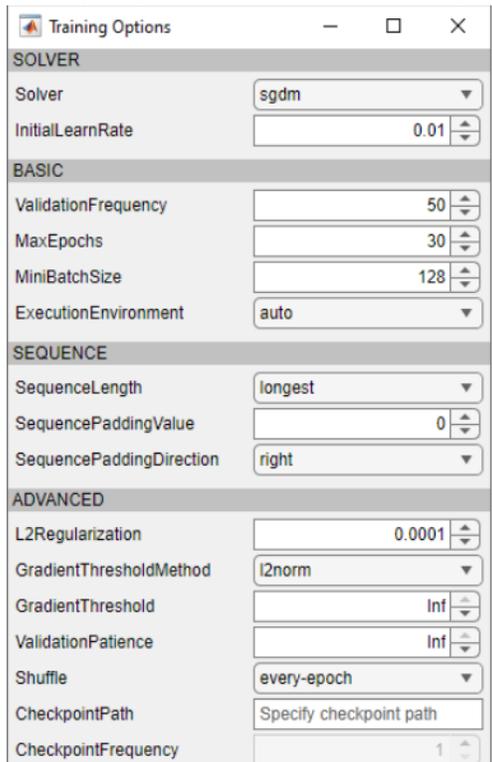
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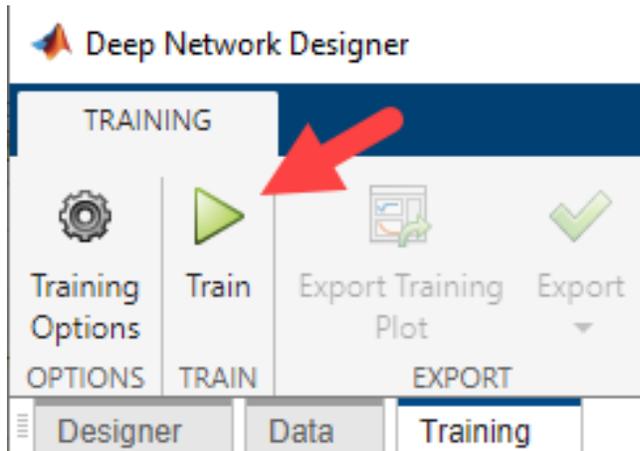
MATLAB支持通过图形化工具设计、训练、验证机器学习模型和深度神经网络模型



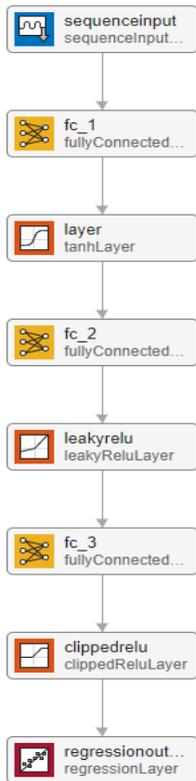
机器学习模型训练，对比和验证



模型超参数设定



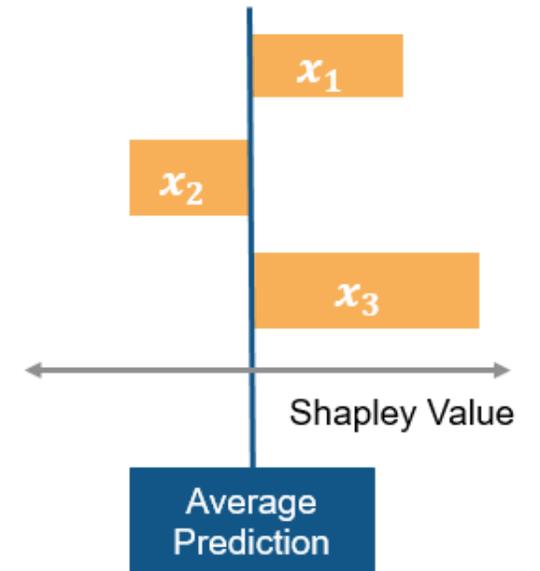
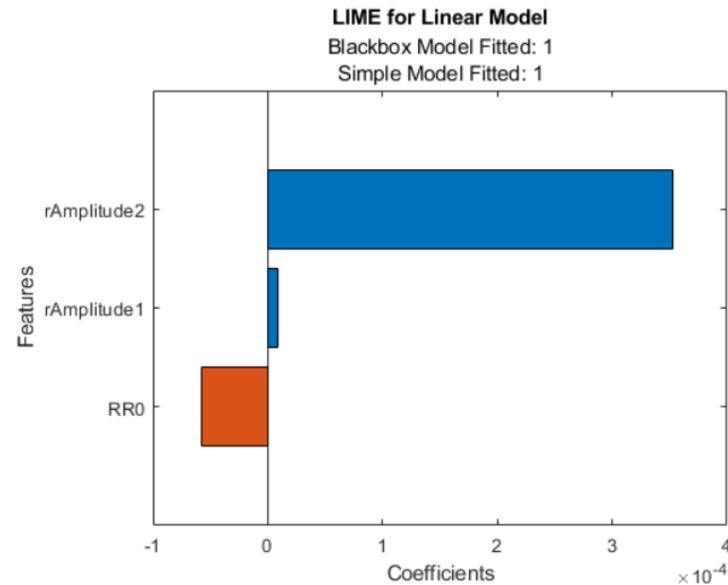
深度神经网络模型训练



深度神经网络设计

机器学习可解释性

- 机器学习模型可解释性
 - Local Interpretable Model-agnostic Explanations (LIME)
 - Partial Dependence Plots (PDP)
 - Shapley values **R2021a**

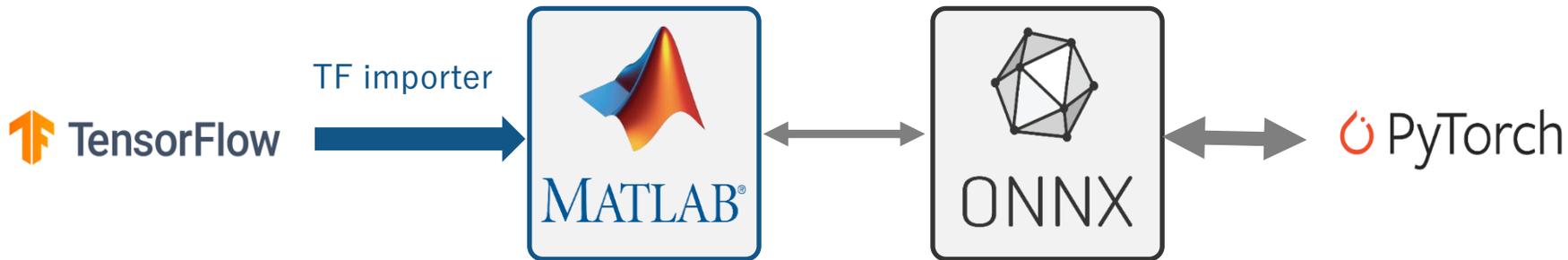


导入第三方平台训练好的深度神经网络模型

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- MATLAB支持直接导入在第三方平台训练好的深度神经网络模型，如TensorFlow、Caffe；
- 也支持导入ONNX（Open Neural Network Exchange）格式
的模型文件



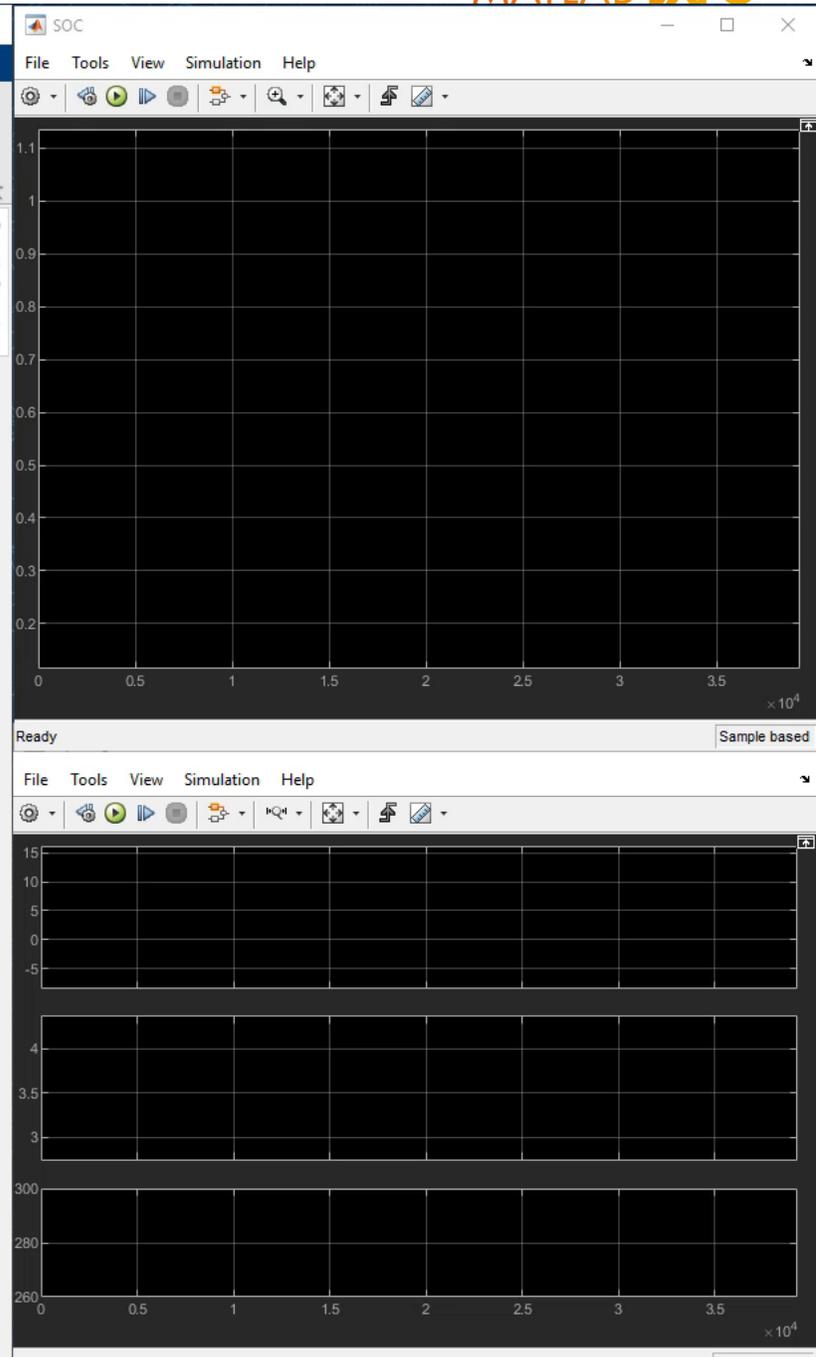
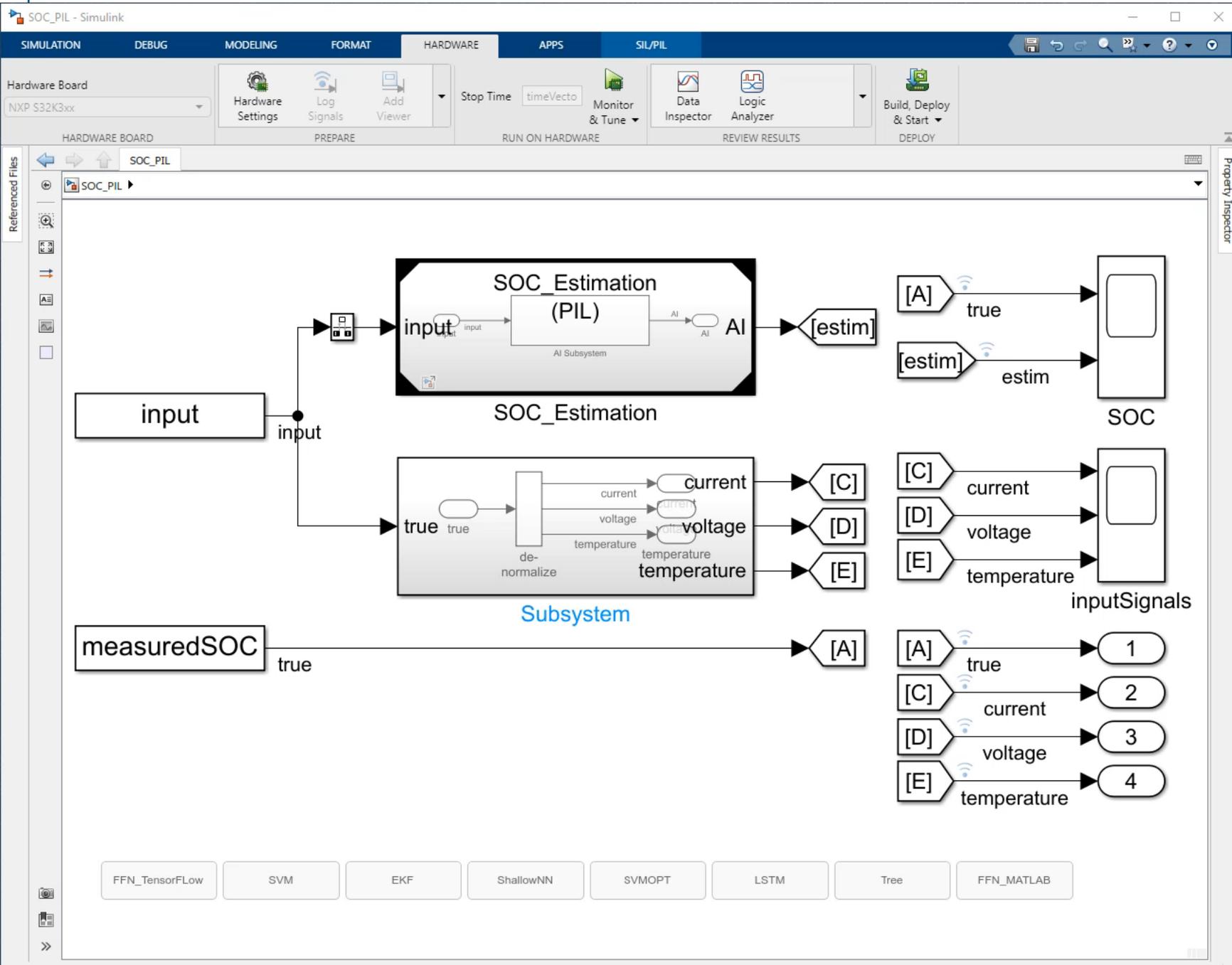
Simulink 仿真测试

- Simulink模块库包含机器学习和深度学习（CNN和LSTM）模块，
- 通过直接拖入的方式引入这些模块
- 并通过配置模型文件关联MATLAB中训练好的机器学习和深度学习神经网络模型

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The screenshot displays the Simulink environment. On the left, the 'Simulink Library Browser' is open to the 'Deep Learning Toolbox/Deep Neural Networks' section, showing various neural network models like 'Image Classifier', 'Predict', and 'Stateful Classify'. The main workspace contains a block diagram with an 'input' block connected to a block labeled u^T . The bottom pane shows a simulation plot with a grid and axes, indicating a 'Sample based' simulation.



模型的部署

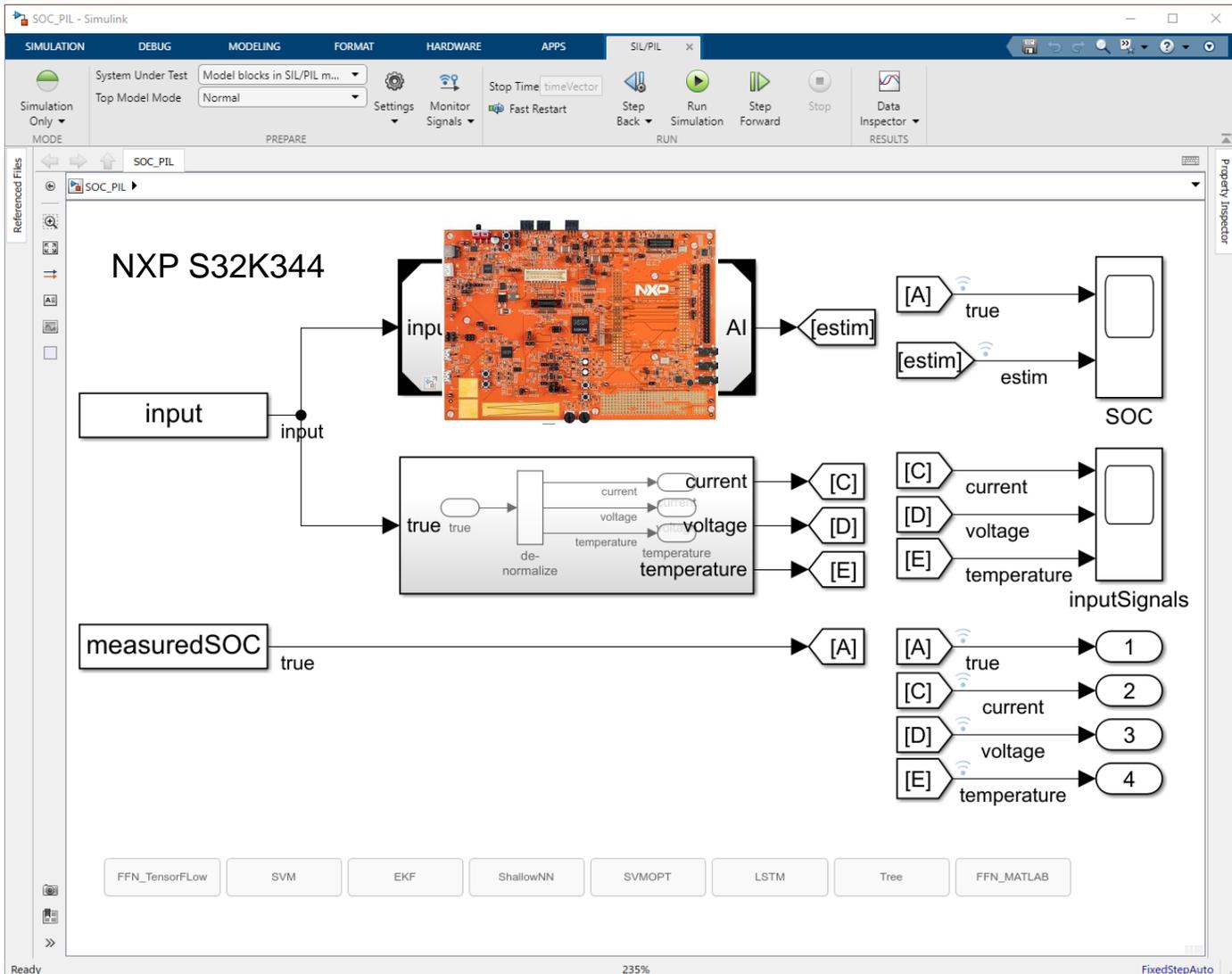
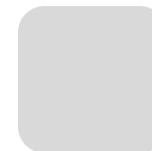
数据预处理

AI建模

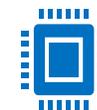
仿真测试

集成部署

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**Automatic Library-Free
C Code**



Any CPU
Inc. ARM Cortex-M



life.augmented
**TEXAS
INSTRUMENTS**

案例：利用NXP目标板构建PIL仿真

The image displays a Simulink environment for a PIL (Program in Loop) simulation of a State of Charge (SOC) estimation system. The main workspace shows a block diagram where an 'input' signal is fed into a 'SOC_Estimation (PIL)' block. This block outputs an 'estim' signal. Additionally, a 'measuredSOC' block outputs a 'true' signal. The 'inputSignals' block provides 'current', 'voltage', and 'temperature' data to the SOC estimation process. The simulation results are shown in three plots: 'true, estim' (SOC), 'current', 'voltage', and 'temperature'. The SOC plot shows a decreasing trend from 1.0 to approximately 0.65 over time. The current plot shows high-frequency oscillations around 0. The voltage plot shows high-frequency oscillations around 3.5. The temperature plot shows a constant value around 260. The Diagnostic Viewer at the bottom shows the build logs for the PIL generation process, including the invocation of the postbuild tool and the generation of the binary outputs.

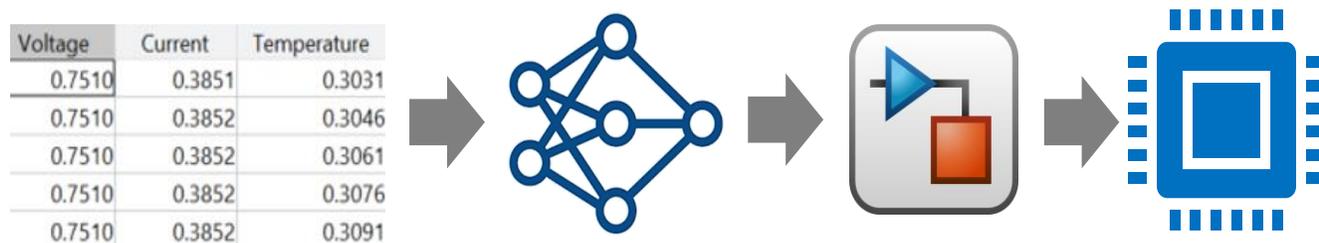
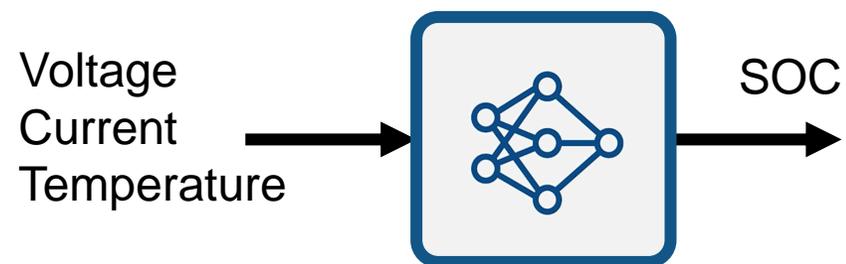
```

    ### Done invoking postbuild tool.
    ### Invoking postbuild tool "ELF To Binary Converter" ...
    arm-none-eabi-objcopy -O binary ./SOC_Estimation.elf ../.././SOC_Estimation.bin
    ### Done invoking postbuild tool.
    ### Successfully generated all binary outputs.

    C:\Users\jgazzarr\OneDrive - MathWorks\Work\Projects\AI_MBD\SOCEstimation\work\slprj\ert\SOC_Estimation\pil\exit /B 0
    ### Updating code generation report with PIL files ...
    ### Starting application: 'work\slprj\ert\SOC_Estimation\pil\SOC_Estimation.elf'
  
```

总结

- MATLAB与Simulink构建AI与MBD集成开发的流程
- MATLAB与Simulink相结合实现基于AI的电池SOC的仿真，验证与部署。



MATLAB EXPO

谢谢



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