

MATLAB EXPO

2021

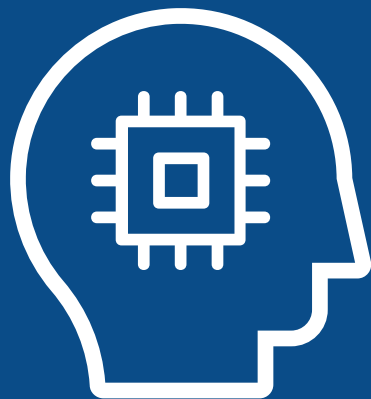
为信号和时间序列构建AI驱动的应用

马文辉, MathWorks



人工智能（AI）技术的演进

ARTIFICIAL INTELLIGENCE



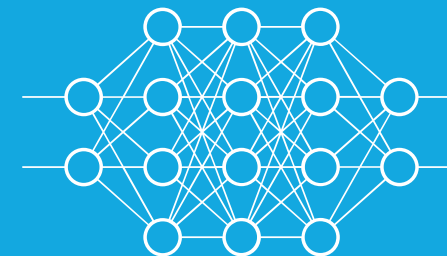
MACHINE LEARNING

Supervised and Unsupervised Statistical Models...



DEEP LEARNING

Neural networks, GANs, Autoencoders...

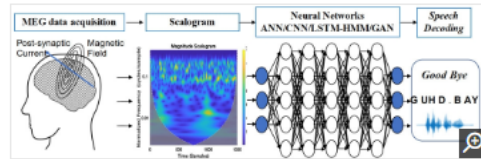


MATLAB用户使用AI模型开发信号或时间序列应用

UT Austin Researchers Convert Brain Signals to Words and Phrases Using Wavelets and Deep Learning

"MATLAB is an industry-standard tool, and one that you can trust. It is easier to learn than other languages, and its toolboxes help you get started in new areas because you don't have to start from scratch."

— Dr. Jun Wang, UT Austin



Classifying the brain signals corresponding to the imagined word "goodbye" using feature extraction and deep neural networks.

Shell performs Seismic Event Detection with Deep Learning

Challenges

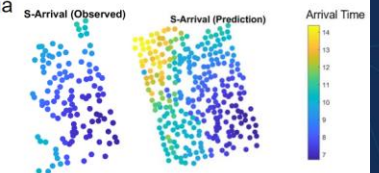
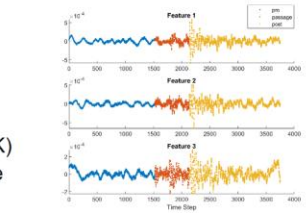
- Terabytes of passive seismic data from geophones
- Traditional methods time/labor intensive (5 months & ~ \$100K)
- Event detection inconsistent/unreliable in 'low' signal to noise records

Solution

- Train LSTM network to detect P-wave and S-wave arrivals via sequence-to-sequence classification

Results

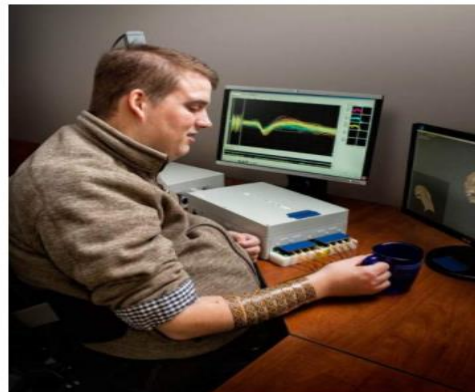
- >98% accuracy for arrival prediction
- Networks generalizes to other data (sites, source mechanisms)



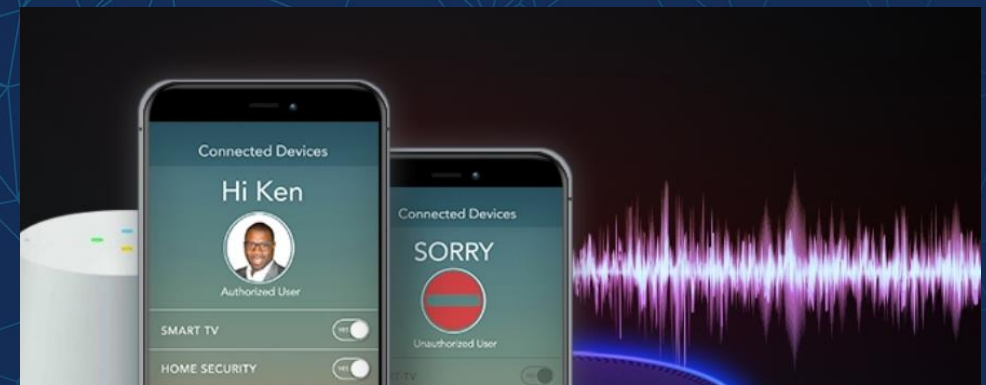
Battelle Neural Bypass Technology Restores Movement to a Paralyzed Man's Arm and Hand

"The algorithms we developed using MATLAB gave the participant back basic control of his arm and hand. By the end of the study, he could grip a bottle, pour out its contents, and set it down, as well as pick up a stir stick and execute a stirring motion."

— David Friedenber, Battelle



Patient using the Battelle NeuroLife system.



Voice Interface: The Touchscreen of the Next Century

How AI and Signal Processing Came Together to Track the DNA of Sound

AI驱动的系统开发流程

数据准备



数据清洗



基于领域知识的数
据处理



仿真数据补充

AI驱动的系统开发流程

数据准备



数据清洗



基于领域知识的数
据处理



仿真数据补充

AI建模



模型设计和参数设
定



硬件加速



训练迭代

AI驱动的系统开发流程

数据准备



数据清洗



基于领域知识的数
据处理



仿真数据补充

AI建模



模型设计和参数设
定



硬件加速



训练迭代

部署



嵌入式设备

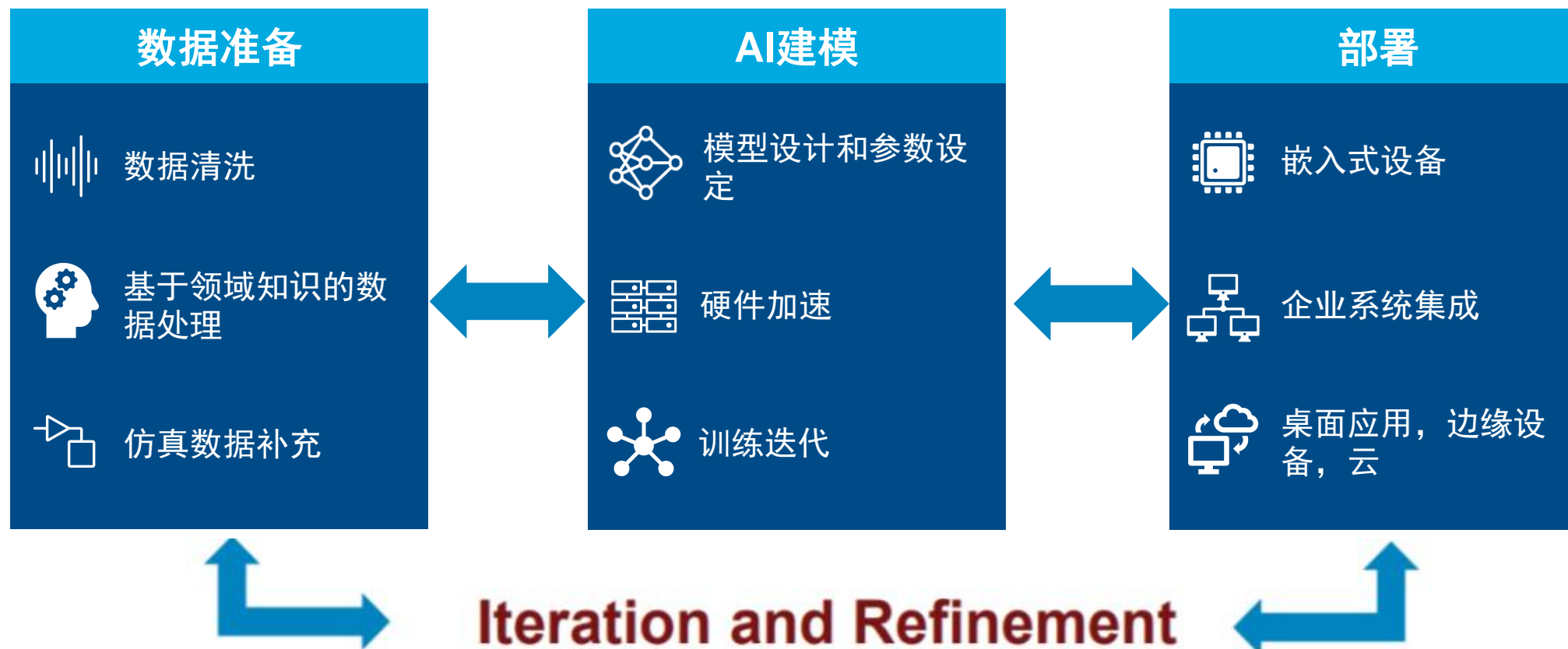


企业系统集成



桌面应用，边缘设
备，云

AI驱动的系统开发流程



数据准备

数据准备



数据清洗



基于领域知识的数据处理



仿真数据补充

数据准备

数据准备



数据清洗



基于领域知识的数据处理



仿真数据补充

Q.如何进行数据的标注?

数据准备

数据准备



数据清洗



基于领域知识的数据处理



仿真数据补充

Q.如何进行数据的标注?

Q.如果不能收集数据怎么办?

使用Signal Labeler app进行信号标注

手动和自动标注

- 标注信号属性、ROI或POI(points of interest)
- 运行自动标注算法
- 查看已标注信息
- 在时域上可视化标注

The screenshot displays the Signal Analyzer app interface with the following components:

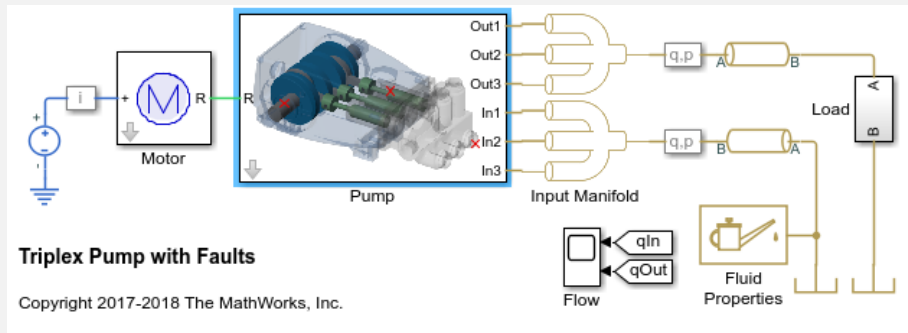
- Top Panel:** Includes tabs for LABEL, DISPLAY, and TIME. The LABEL tab is active, showing options for adding definitions, ROI (Region of Interest) settings, and value selection (currently LFM).
- Label Definitions:** A list of defined labels, including 'SignalSource' and 'WaveformType' (selected).
- Labeled Signal Set:** A table showing the current signal set with columns for Name, Plot, Value, Location (Min), and Location (Max).

Name	Plot	Value	Location (Min)	Location (Max)
▼ X				
X(:,1)	<input checked="" type="checkbox"/>			
X(:,2)	<input type="checkbox"/>			
SignalSource		Receiver1		
WaveformT...				
- Waveform Plots:** Two plots are shown. The top plot displays the signal X(:,1) over 6000 samples, with a blue waveform. The bottom plot, titled 'WaveformType', shows a dark bar representing the signal's classification over the same time period.

数据生成 (Synthetic Data)

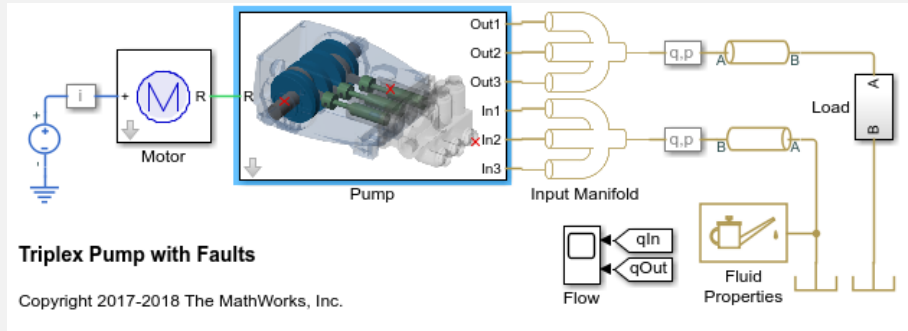
数据生成 (Synthetic Data)

Simulate data using Simulink models

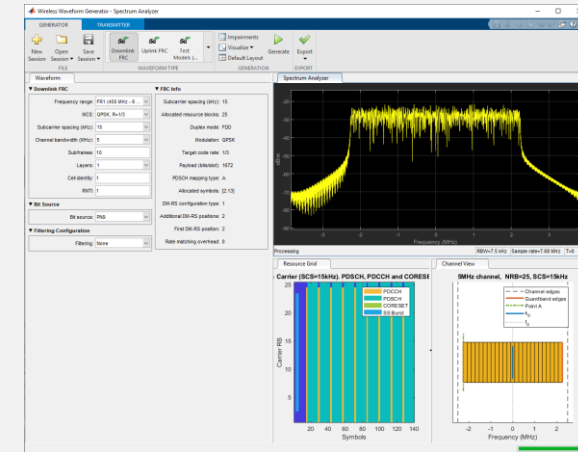


数据生成 (Synthetic Data)

Simulate data using Simulink models

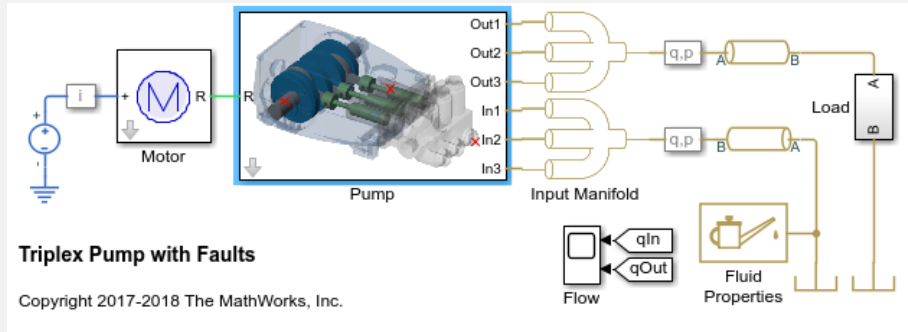


Generate wireless waveforms

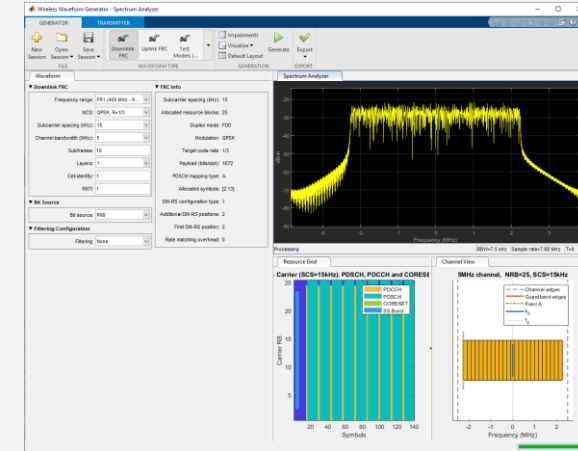


数据生成 (Synthetic Data)

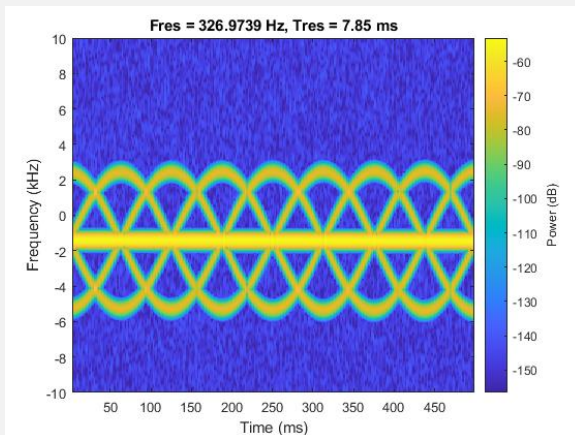
Simulate data using Simulink models



Generate wireless waveforms

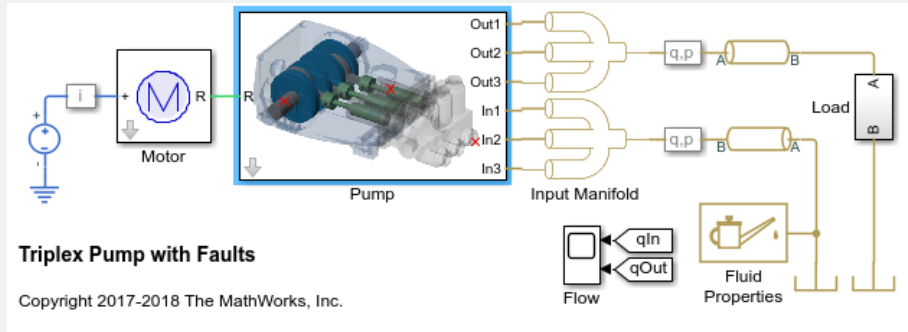


Generate Radar Returns

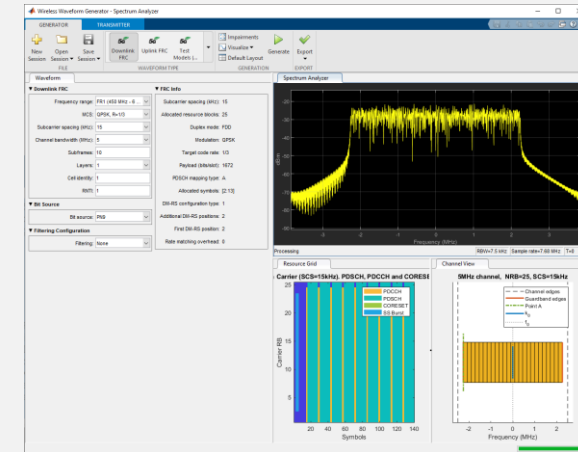


数据生成 (Synthetic Data)

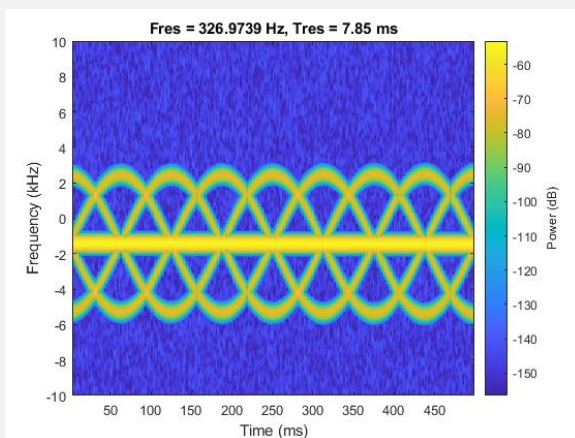
Simulate data using Simulink models



Generate wireless waveforms

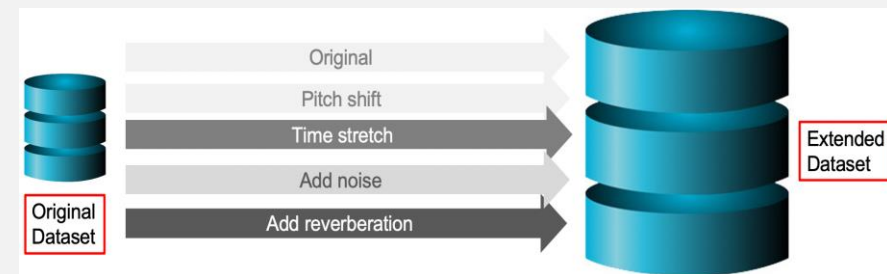


Generate Radar Returns



Generate and Augment Audio Data

text2speech



特征提取

数据准备



数据清洗



基于领域知识的数据处理



仿真数据补充

特征提取

数据准备



数据清洗



基于领域知识的数据处理



仿真数据补充

Q. 原始数据可以直接使用吗?

特征提取

数据准备



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基于领域知识的数据处理



仿真数据补充

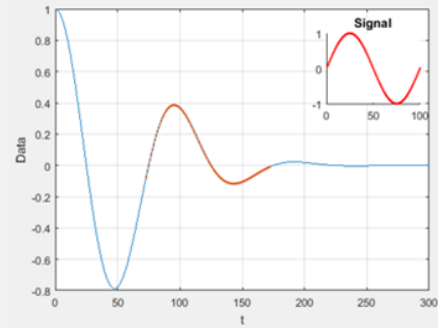
Q.原始数据可以直接使用吗?

Q. 如何提取正确的数据特征?

信号数据特征提取

信号数据特征提取

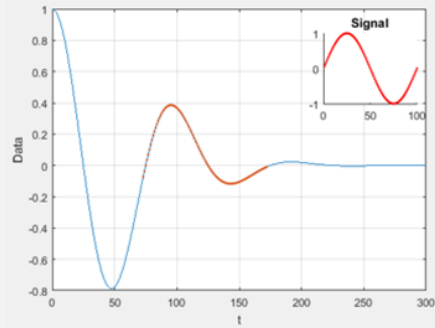
Time-Domain Features



- Signal Patterns
- Changepoints
- Peaks
- Signal Envelope
-

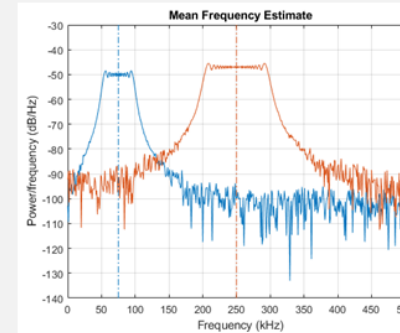
信号数据特征提取

Time-Domain Features



- Signal Patterns
- Changepoints
- Peaks
- Signal Envelope
-

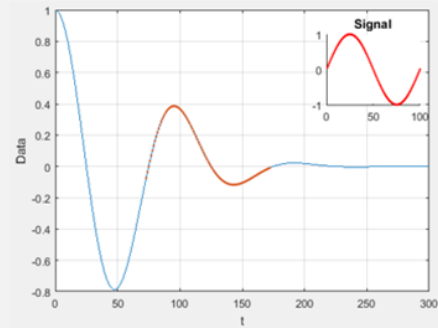
Frequency-Domain Features



- BW measurements
- Spectral Statistics
- Octave Spectrum
-

信号数据特征提取

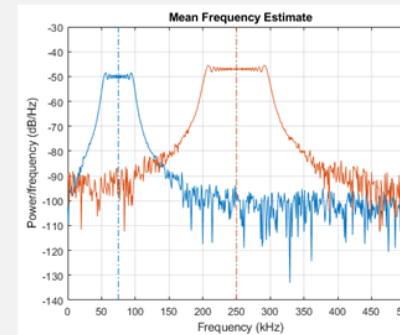
Time-Domain Features



- Signal Patterns
- Changepoints
- Peaks
- Signal Envelope

.....

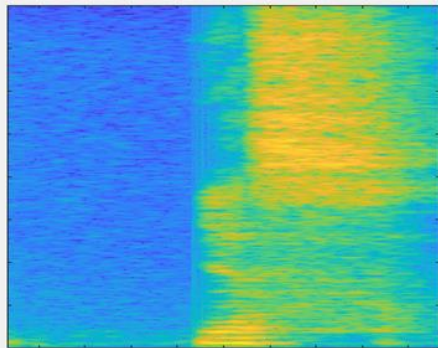
Frequency-Domain Features



- BW measurements
- Spectral Statistics
- Octave Spectrum

.....

Time-Frequency features

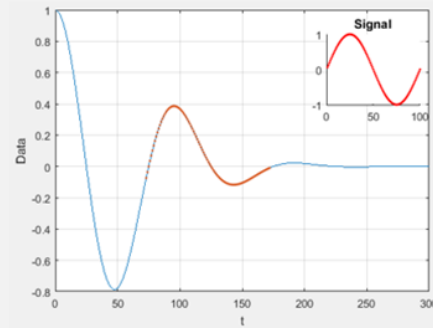


- STFT
- CWT
- Constant-Q Transform

.....

信号数据特征提取

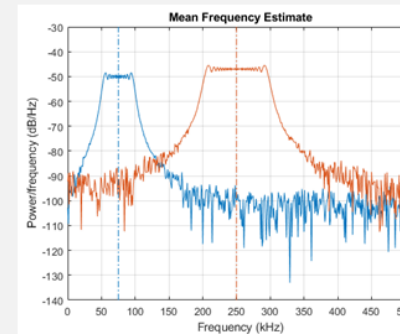
Time-Domain Features



- Signal Patterns
- Changepoints
- Peaks
- Signal Envelope

.....

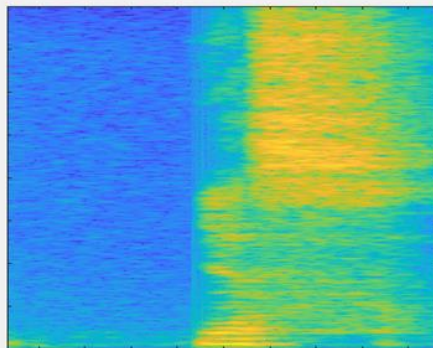
Frequency-Domain Features



- BW measurements
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- Octave Spectrum

.....

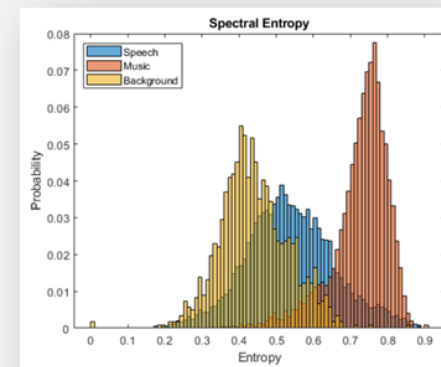
Time-Frequency features



- STFT
- CWT
- Constant-Q Transform

.....

Domain-Specific Features



- Speech and audio
- Navigation and Sensor Fusion
- Radar
- Communication

.....

数据建模 (AI Model)

AI建模



模型设计和参数设定



硬件加速



训练迭代

数据建模 (AI Model)

AI建模



模型设计和参数设定



硬件加速



训练迭代

Q. 如何选取正确的模型?

数据建模 (AI Model)

AI建模



模型设计和参数设定



硬件加速



训练迭代

Q. 如何选取正确的模型:

- 如果没有足够的训练数据?
- 如果没有数据科学相关经验?
- 如果需要简单的交互模型?

.....

MATLAB构建AI模型

```
imageInputLayer([2 spf 1], 'Name', 'Input Layer')  
  
convolution2dLayer(filterSize, 'Name', 'CNN1')  
  
batchNormalizationLayer('Name', 'BN1')  
reluLayer('Name', 'ReLU1')  
maxPooling2dLayer(poolSize, 'Name', 'MaxPool1')
```

fitcauto/fitrauto

自动机器学习

MATLAB构建AI模型

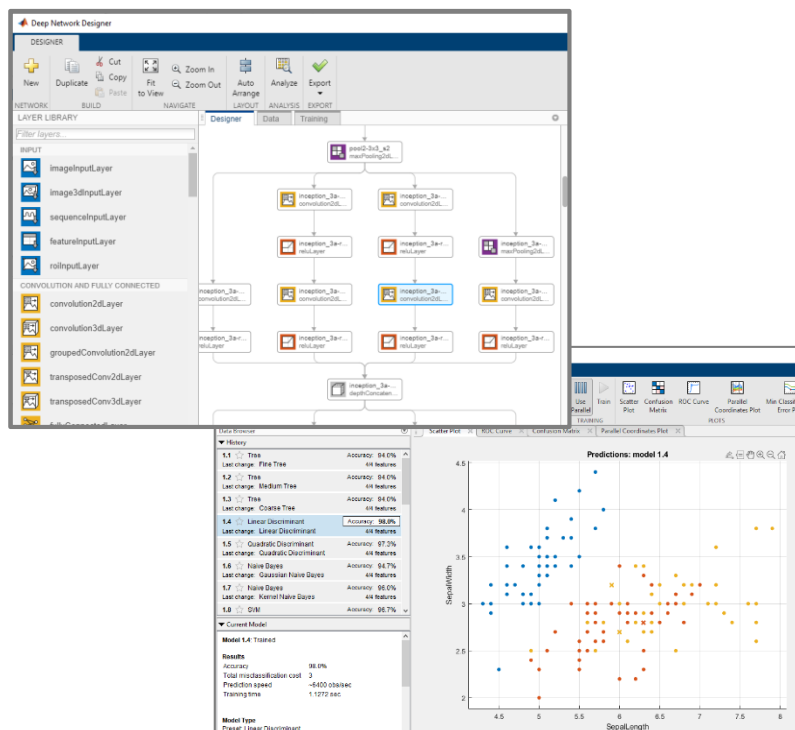
```
imageInputLayer([2 spf 1], 'Name', 'Input Layer')

convolution2dLayer(filterSize, 'Name', 'CNN1')

batchNormalizationLayer('Name', 'BN1')
reluLayer('Name', 'ReLU1')
maxPooling2dLayer(poolSize, 'Name', 'MaxPool1')
```

fitcauto/fitrauto

自动机器学习



Apps: 图形化的应用

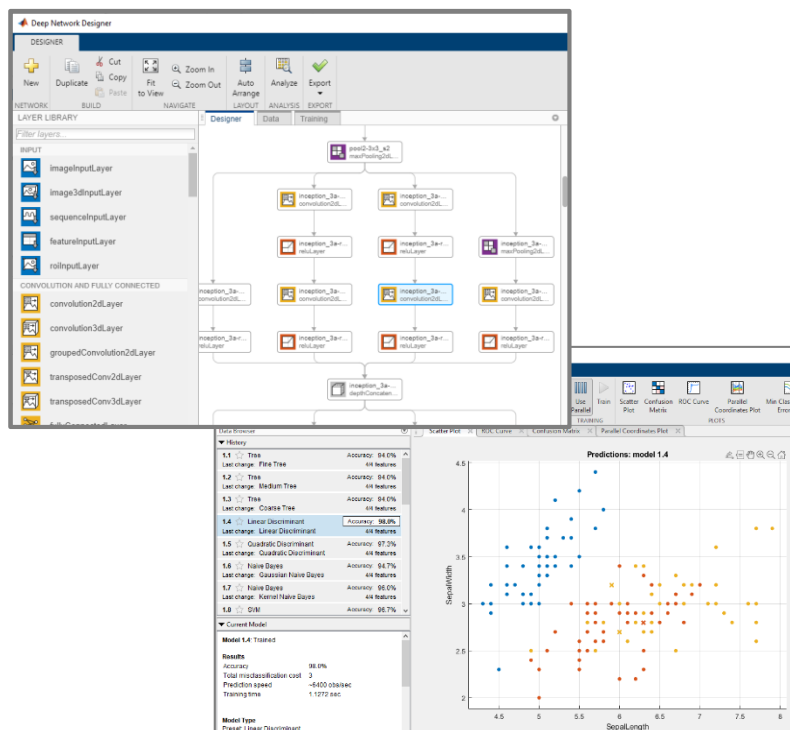
MATLAB构建AI模型

```

imageInputLayer([2 spf 1], 'Name', 'Input Layer')

convolution2dLayer(filterSize, 'Name', 'CNN1')

batchNormalizationLayer('Name', 'BN1')
reluLayer('Name', 'ReLU1')
maxPooling2dLayer(poolSize, 'Name', 'MaxPool1')
    
```



- Inception-v3
- ResNet-101
- VGG-16
- Inception-ResNet-v2
- ResNet-18
- GoogLeNet
- DenseNet-201
- VGG-19
- SqueezeNet
- AlexNet
- ResNet-50

fitcauto/fitrauto

自动机器学习

Apps: 图形化的应用

迁移学习

MATLAB App 提高生产力

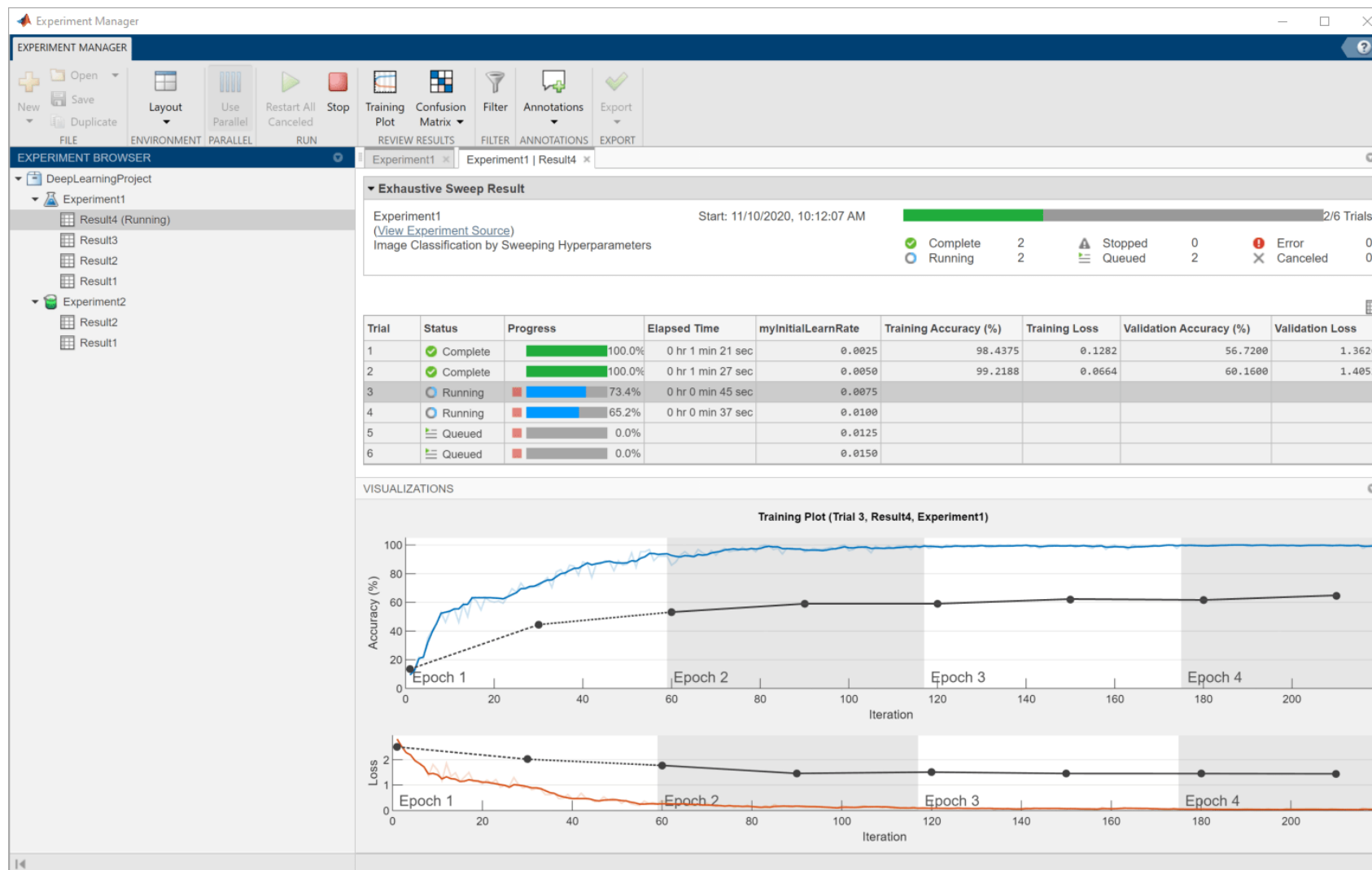
MATLAB App 提高生产力 - Experiment Manager App

The screenshot displays the MATLAB Experiment Manager App interface. The top toolbar includes options for file management (New, Open, Save, Duplicate), environment control (Layout, Use Parallel, Restart All, Stop), and analysis (Training Plot, Confusion Matrix, Filter, Annotations, Export). The left sidebar shows a project tree with 'Experiment1' selected, containing results 1 through 4. The main panel shows the 'Exhaustive Sweep Result' for 'Experiment1', which started on 11/10/2020 at 10:12:07 AM. A summary table indicates 2 complete trials, 2 running trials, and 2 queued trials. Below this is a detailed table of trial results.

Trial	Status	Progress	Elapsed Time	myInitialLearnRate	Training Accuracy (%)	Training Loss	Validation Accuracy (%)	Validation Loss
1	Complete	100.0%	0 hr 1 min 21 sec	0.0025	98.4375	0.1282	56.7200	1.3626
2	Complete	100.0%	0 hr 1 min 27 sec	0.0050	99.2188	0.0664	60.1600	1.4052
3	Running	73.4%	0 hr 0 min 45 sec	0.0075				
4	Running	65.2%	0 hr 0 min 37 sec	0.0100				
5	Queued	0.0%		0.0125				
6	Queued	0.0%		0.0150				

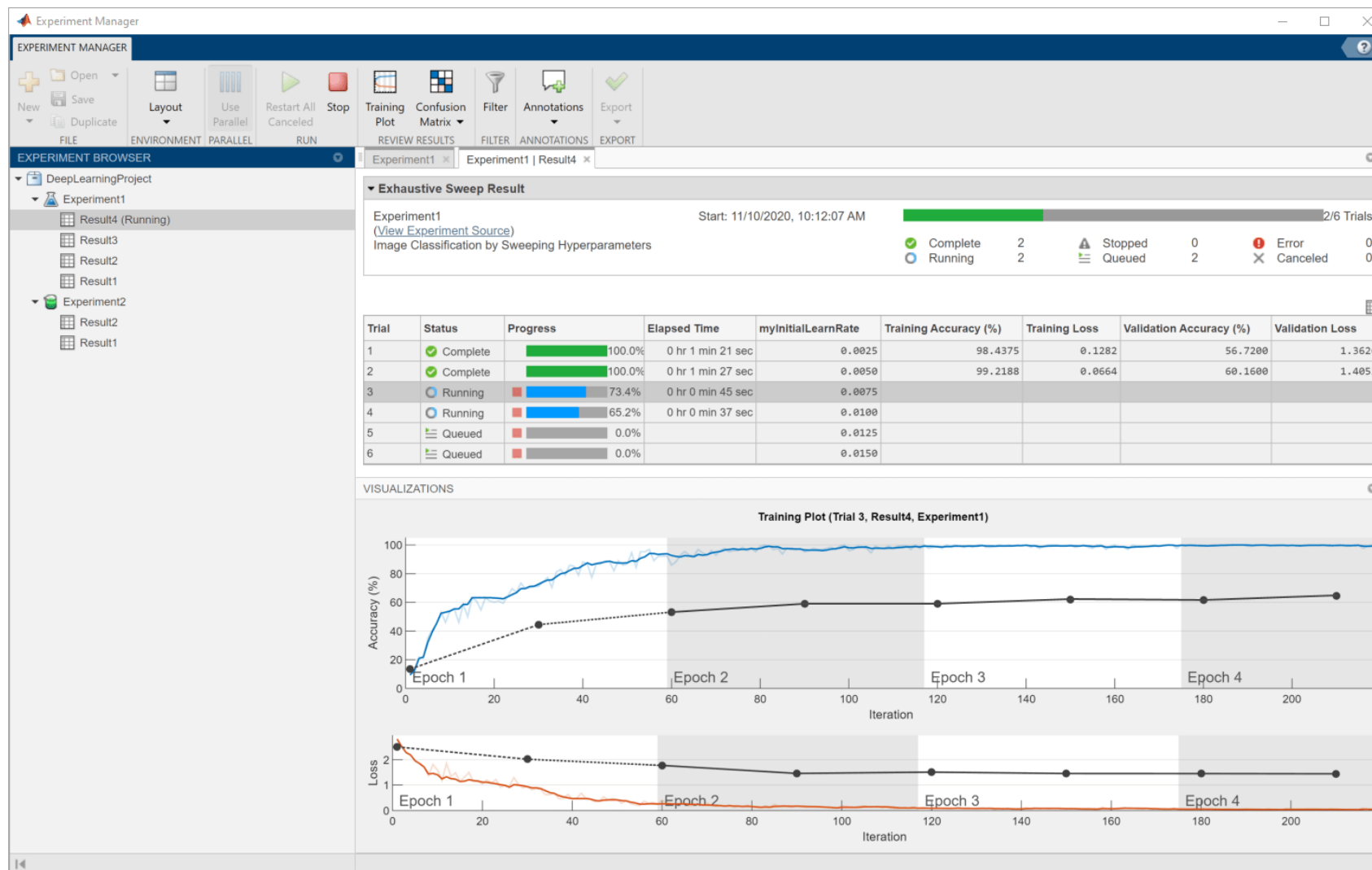
The 'VISUALIZATIONS' section contains two plots for 'Trial 3, Result4, Experiment1'. The top plot, 'Training Plot', shows Accuracy (%) on the y-axis (0 to 100) and Iteration on the x-axis (0 to 200). It features a solid blue line for training accuracy and a dashed black line for validation accuracy. The bottom plot shows Loss on the y-axis (0 to 2) and Iteration on the x-axis (0 to 200), with a solid red line for training loss and a dashed black line for validation loss. Both plots are divided into four epochs: Epoch 1 (0-60 iterations), Epoch 2 (60-120 iterations), Epoch 3 (120-180 iterations), and Epoch 4 (180-200 iterations).

MATLAB App提高生产力 - Experiment Manager App



发现最佳训练参数

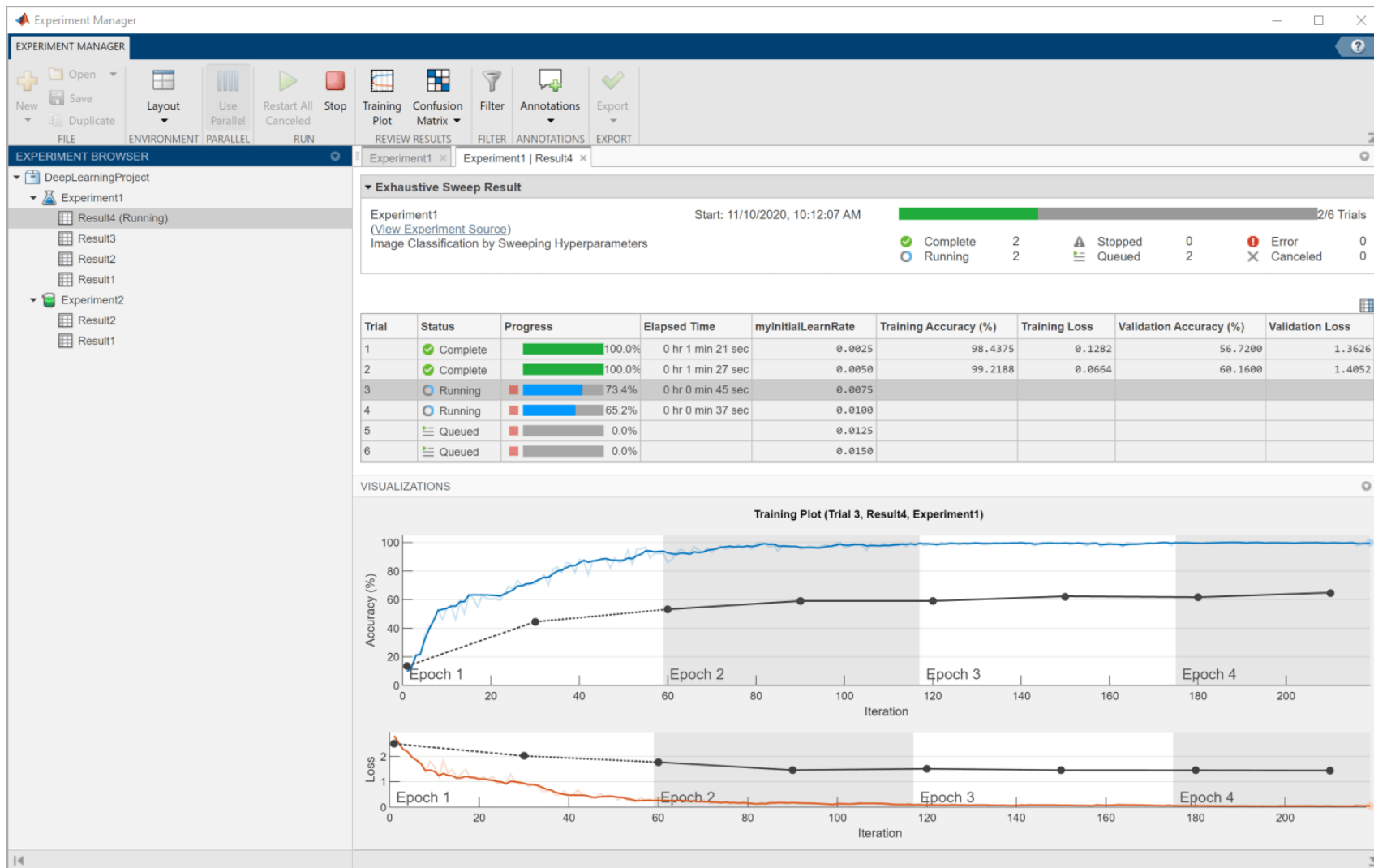
MATLAB App提高生产力 - Experiment Manager App



发现最佳训练参数

比较不同数据集下的
模型精度

MATLAB App提高生产力 - Experiment Manager App

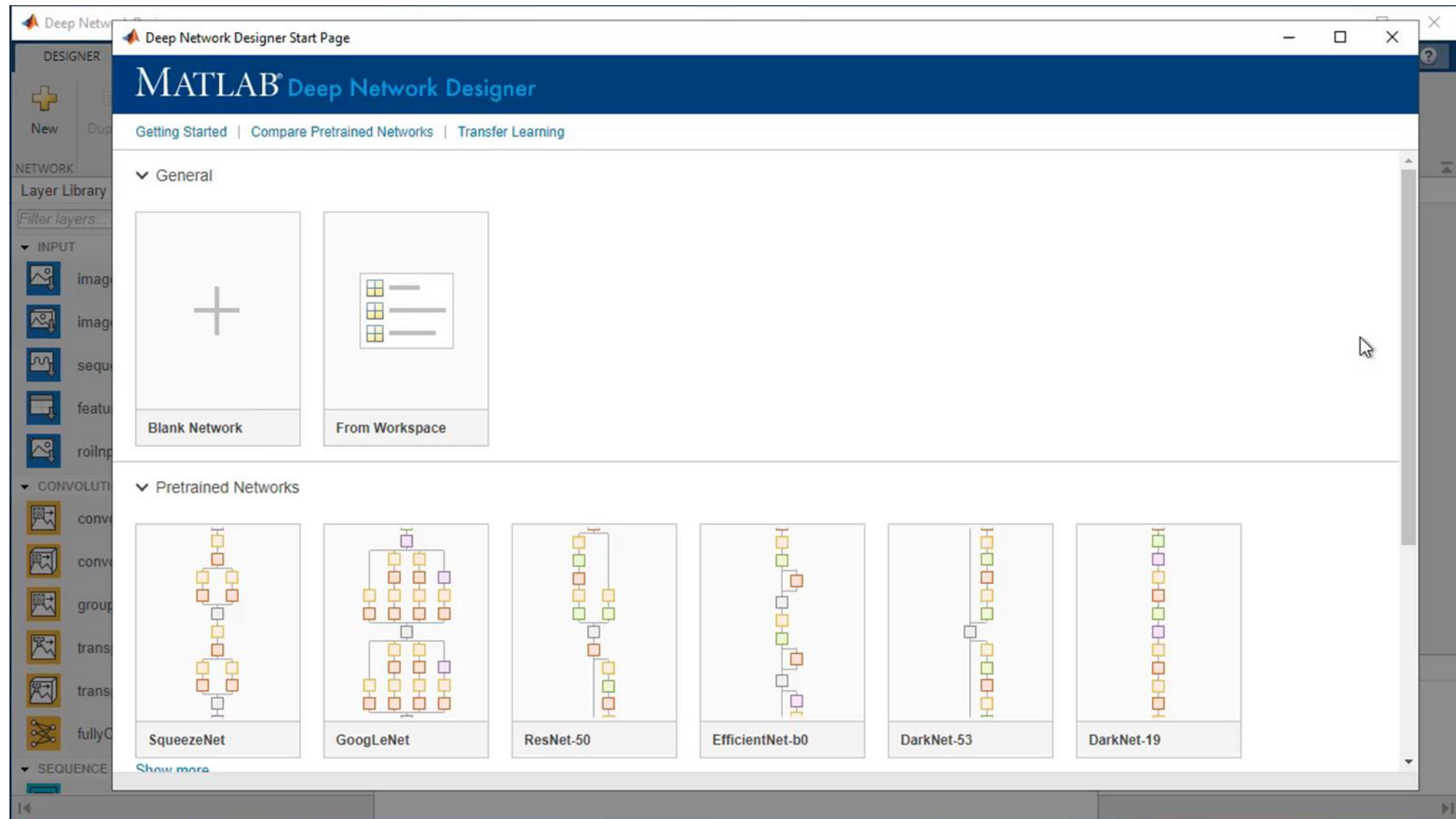


发现最佳训练参数

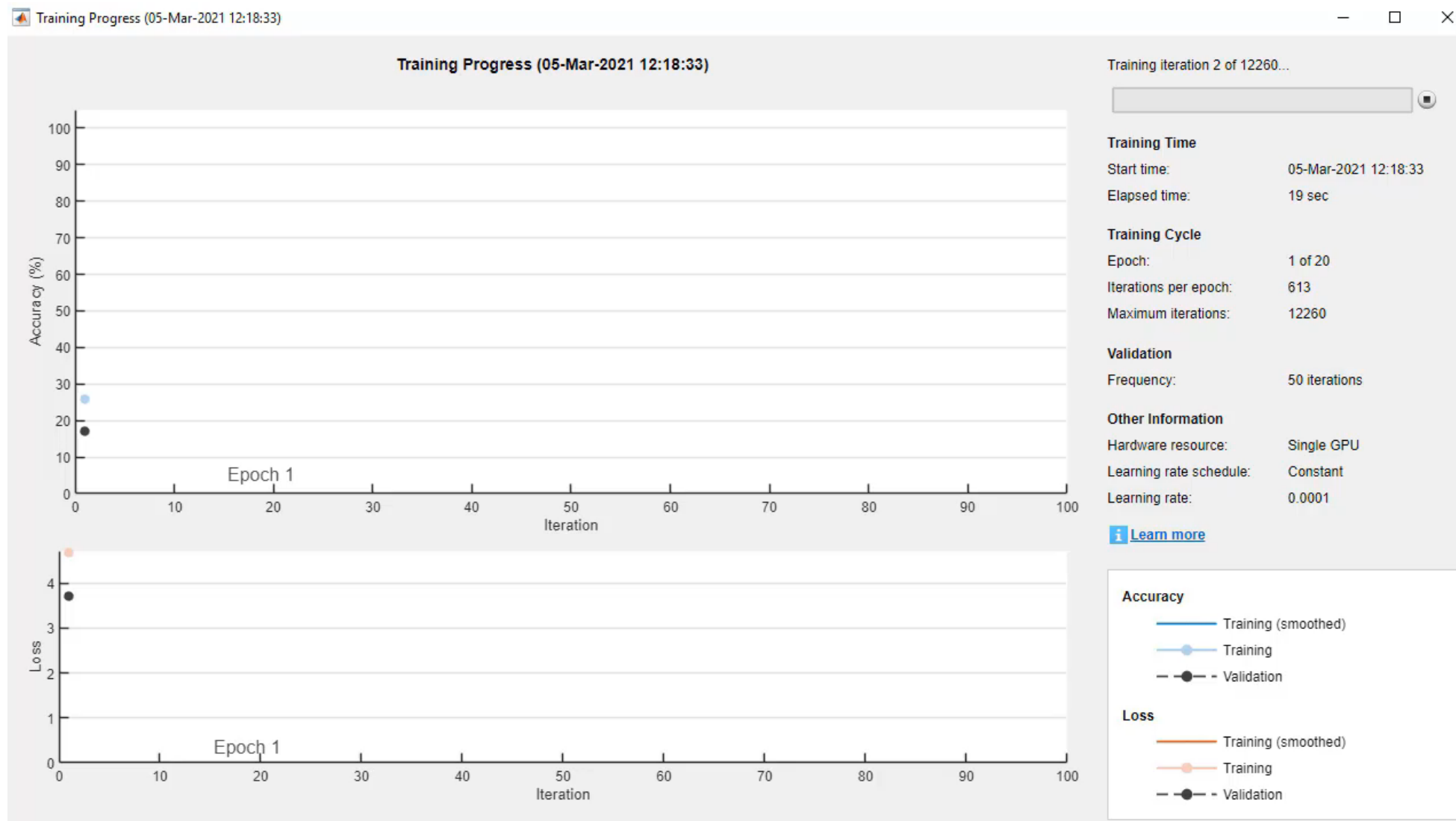
比较不同数据集下的
模型精度

比较同一数据集下不
同模型的精度

MATLAB App提高生产力 - Deep Network Designer



MATLAB App提高生产力 - Deep Network Designer



AI驱动的系统开发流程

数据准备



数据清洗



基于领域知识的数据处理



仿真数据补充

AI建模



模型设计和参数设定



硬件加速



训练迭代

部署



嵌入式设备



企业系统集成



桌面应用，边缘设备，云

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嵌入式设备



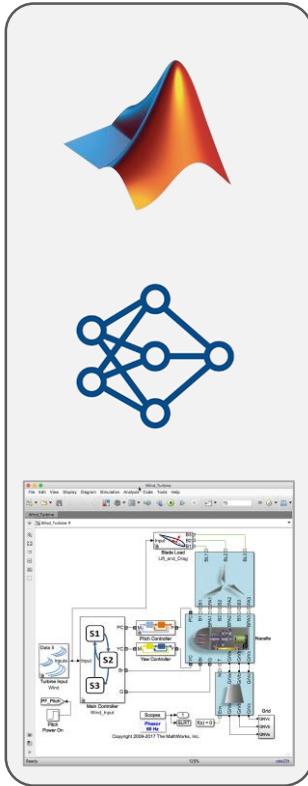
企业系统集成



桌面应用，边缘设备，云

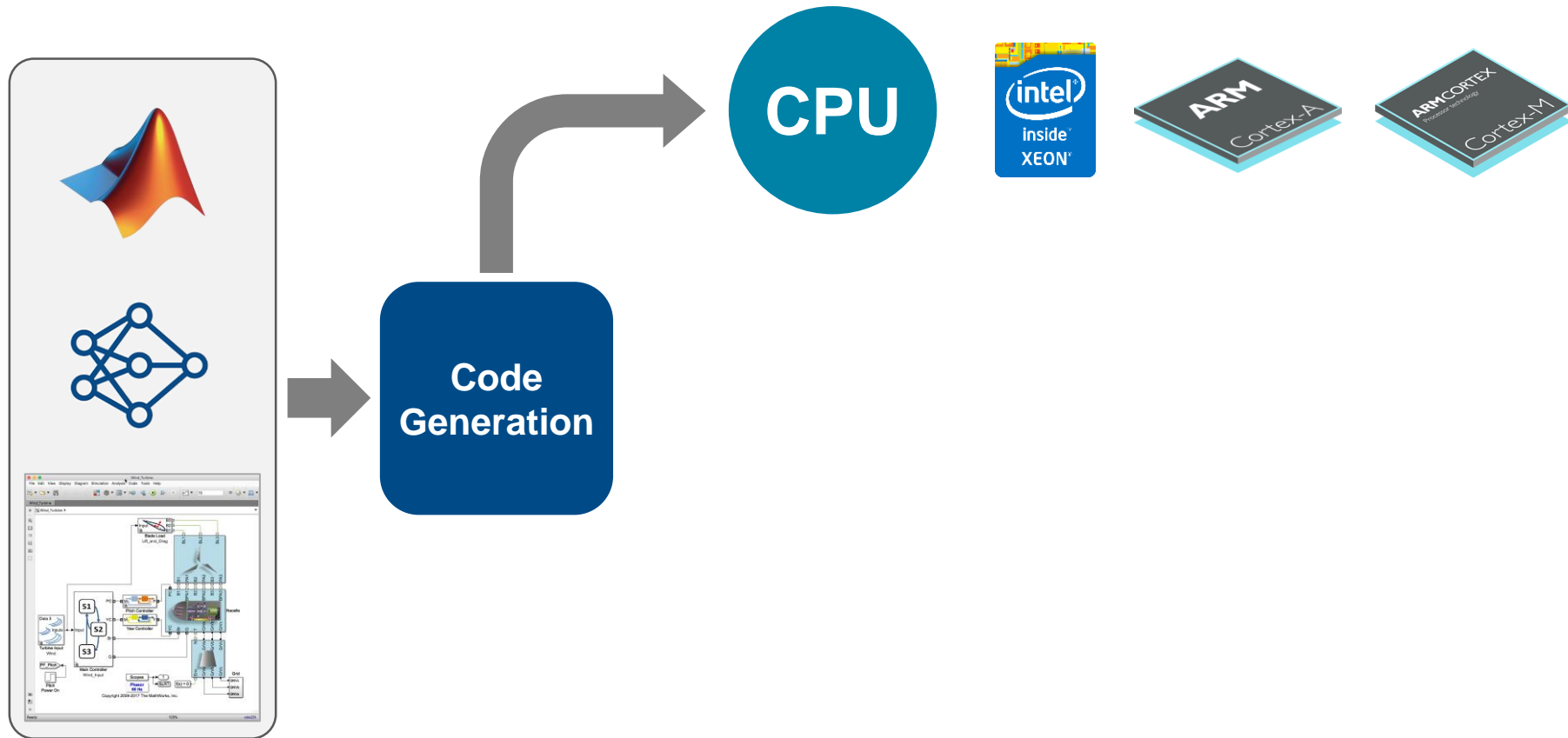
部署到实现最佳性能的处理器

部署到实现最佳性能的处理器的



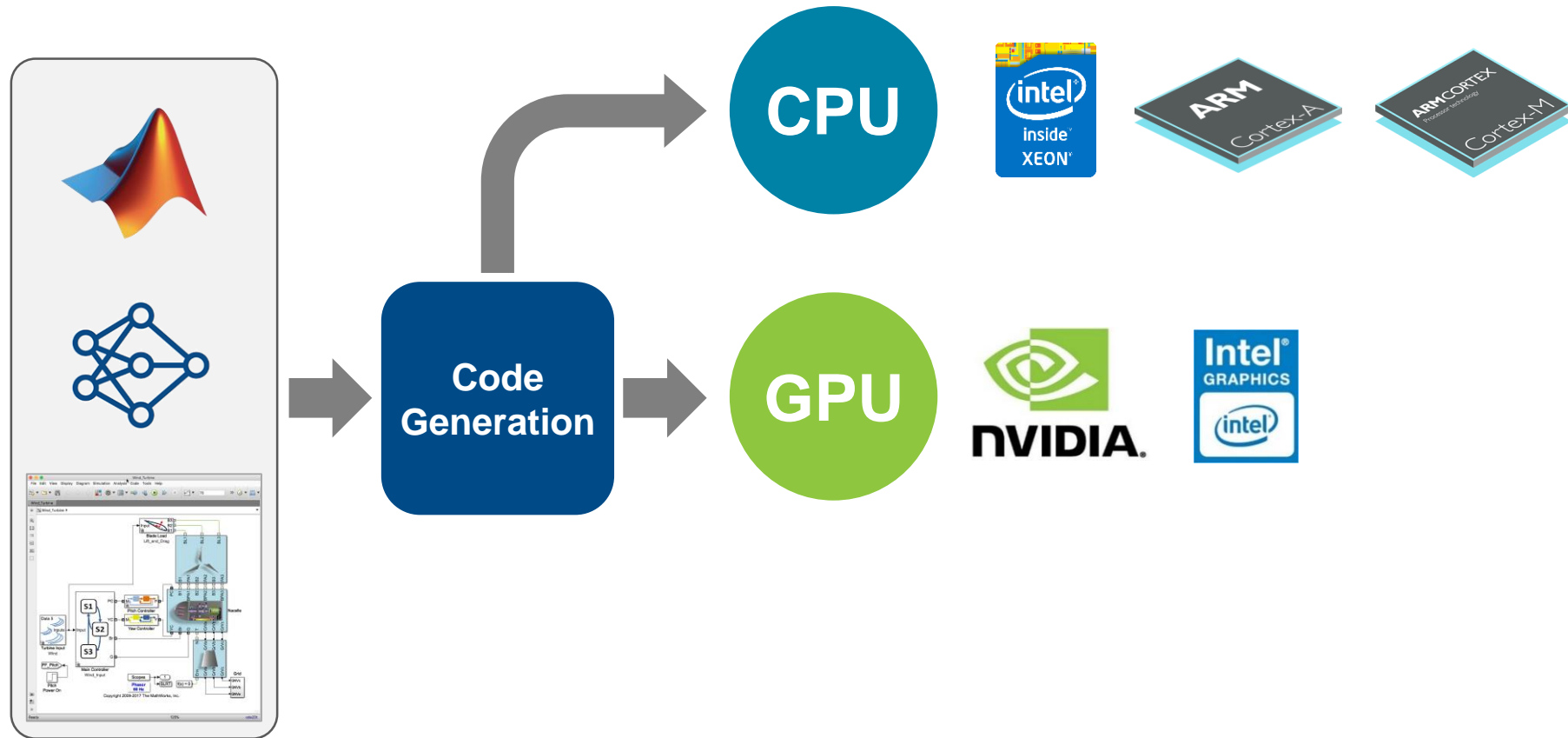
**Preprocessing, Feature
Extraction, AI Model**

部署到实现最佳性能的处理器的



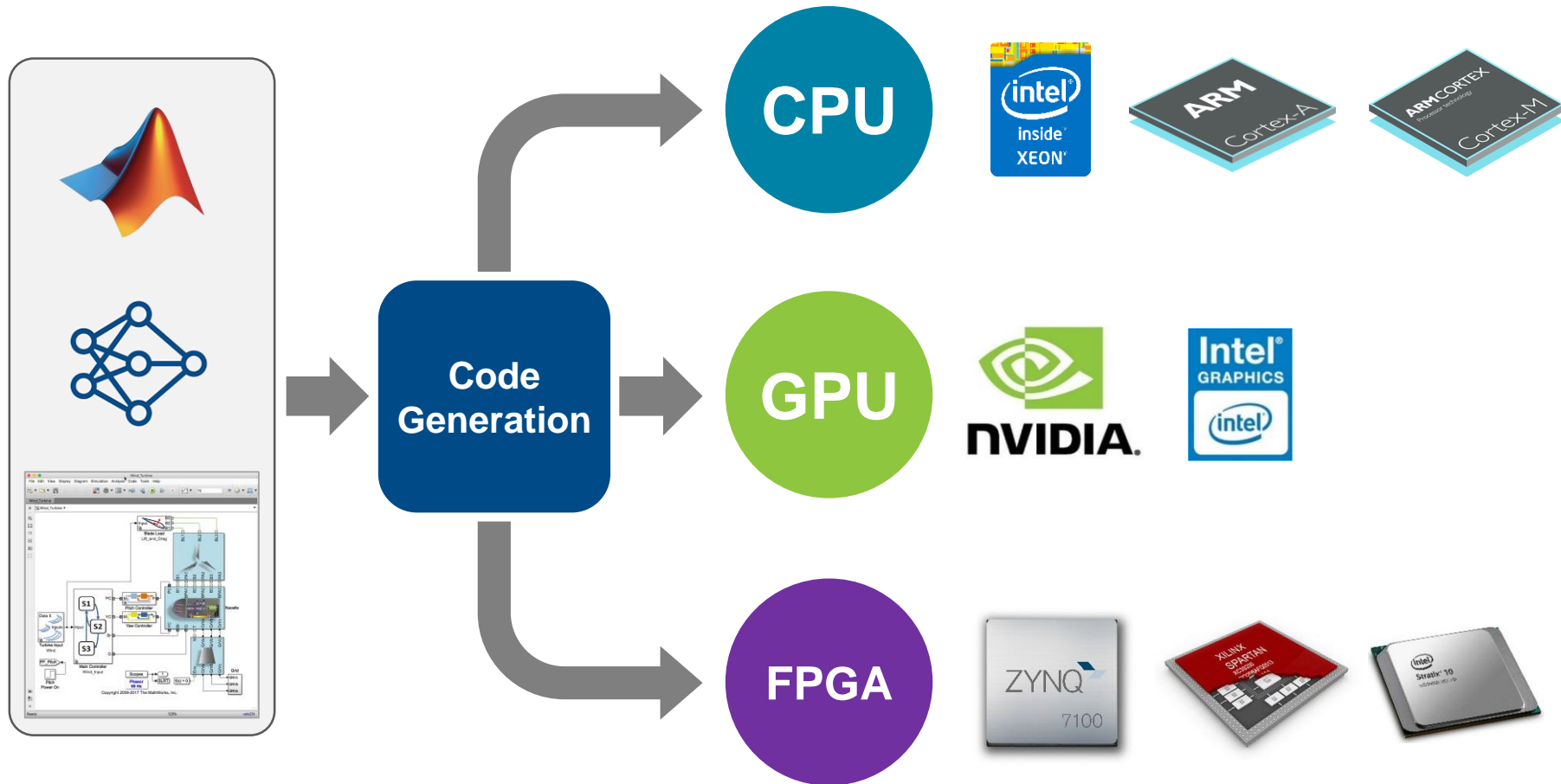
**Preprocessing, Feature
Extraction, AI Model**

部署到实现最佳性能的处理器



**Preprocessing, Feature
Extraction, AI Model**

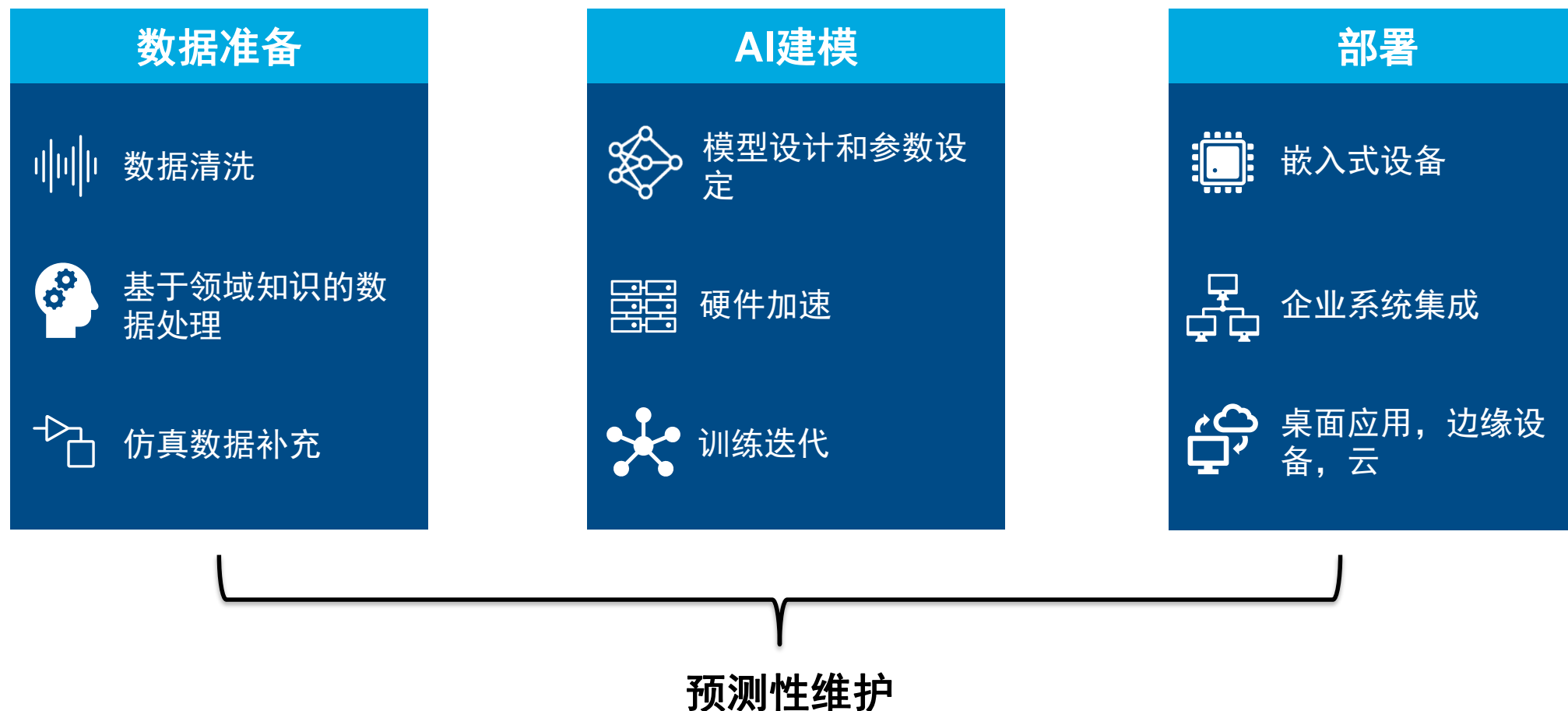
部署到实现最佳性能的处理器



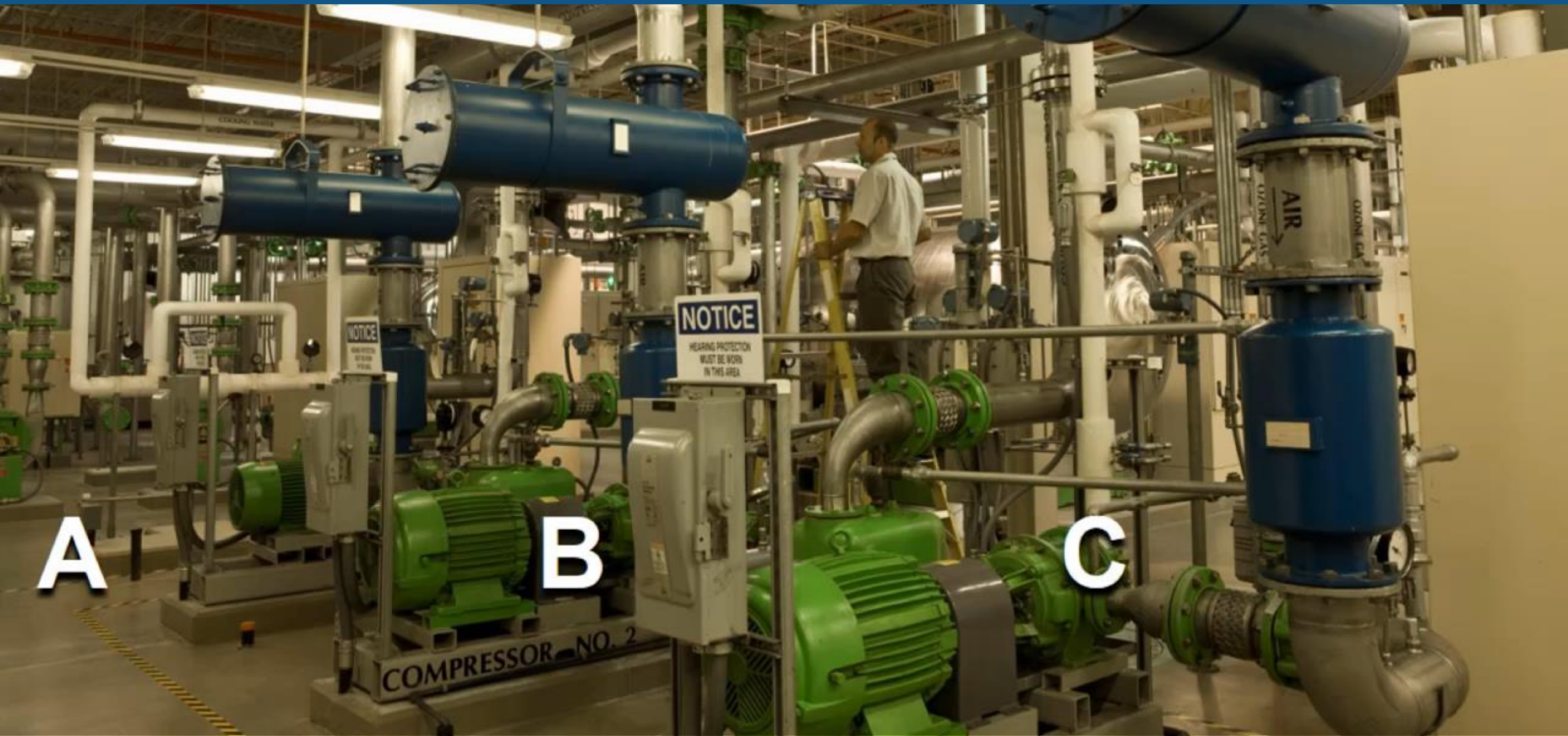
Preprocessing, Feature
Extraction, AI Model

AI技术在工业领域的应用 – 预测性维护

基于AI驱动的系统开发流程实现预测性维护

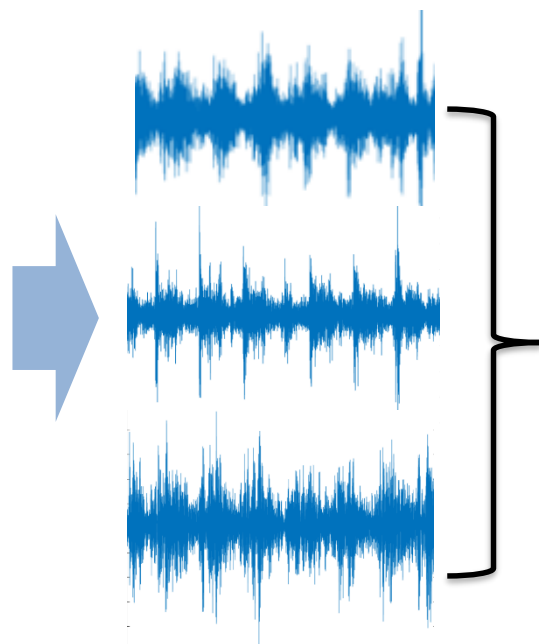
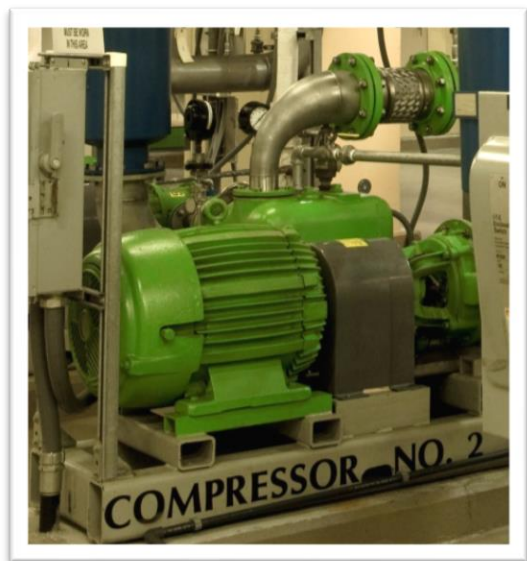


听听看，哪个压缩机的轴承故障？



声音数据采集

- 通过传感器采集声学信号的时间序列数据
- 根据维护日志标注故障类型




1. 健康状态
2. 入口阀泄露
3. 出口阀泄露
4. 单向阀故障
5. 活塞环故障
6. 飞轮故障
7. 传送带故障
8. 轴承故障

	Label	Count
1	Bearing	203
2	Flywheel	203
3	Healthy	203
4	LIV	203
5	LOV	203
6	NRV	203
7	Piston	203
8	Riderbelt	203

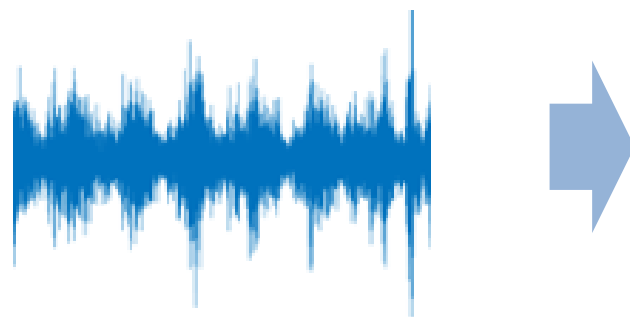
数据准备

 数据清洗

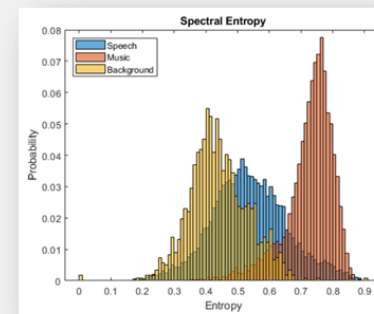
 基于领域知识的数据处理

 仿真数据补充

Audio Toolbox – 特征提取



Domain-Specific Features



- Speech and audio
- Navigation and Sensor Fusion
- Radar
- Communication
-

	1	2	3	4	5	6	7	8	9	10
1	-1.7327	0.6736	-0.2549	-1.5637	1.6215	3.0901	-2.2351	3.4670	0.9090	-2.1155
2	-0.6945	-0.4338	0.5131	-0.4466	1.5556	0.2420	-0.4189	0.8727	-0.0454	-0.5248
3	-0.5121	1.9210	0.5216	-1.3213	-0.2902	-0.0543	-0.5145	0.1455	-0.2633	-0.0819
4	0.4532	0.6668	0.4834	0.0855	-0.5248	-0.1830	1.6840	-0.3684	-0.0121	0.9764
5	0.6505	1.4595	0.4353	-0.2087	0.3480	-0.2585	1.4928	-0.6599	0.4925	1.6933
6	-0.9904	2.2094	0.5543	-1.9034	-0.7336	0.1350	-0.6101	0.9072	-0.1250	-0.5624
7	0.8333	-0.4412	0.3763	0.8538	-0.1206	-0.2486	1.3017	-0.6548	0.5837	1.3158
8	0.0630	-0.3380	0.4176	0.2270	-0.2951	-0.1828	0.9193	-0.2509	0.5698	0.6503
9	-0.2130	-0.0888	0.3596	0.1107	-0.5436	-0.1146	0.5370	-0.0191	0.7044	0.0562

```

aFE = audioFeatureExtractor('SampleRate',16e3, ...
    'Window',hamming(windowLength,'periodic'),...
    'OverlapLength',overlapLength,...
    'spectralCentroid',true, ...
    'spectralCrest',true, ...
    'spectralDecrease',true, ...
    'spectralEntropy',true,...
    'spectralFlatness',true,...
    'spectralFlux',false,...
    'spectralKurtosis',true,...
    'spectralRolloffPoint',true,...
    'spectralSkewness',true,...
    'spectralSlope',true,...
    'spectralSpread',true);
    
```

AI建模



模型设计和参数设定



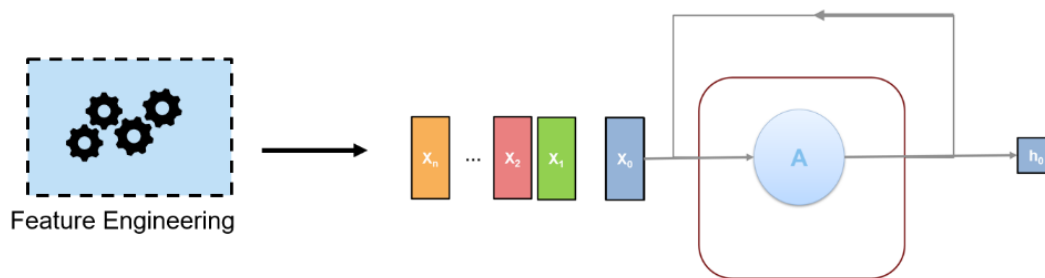
硬件加速



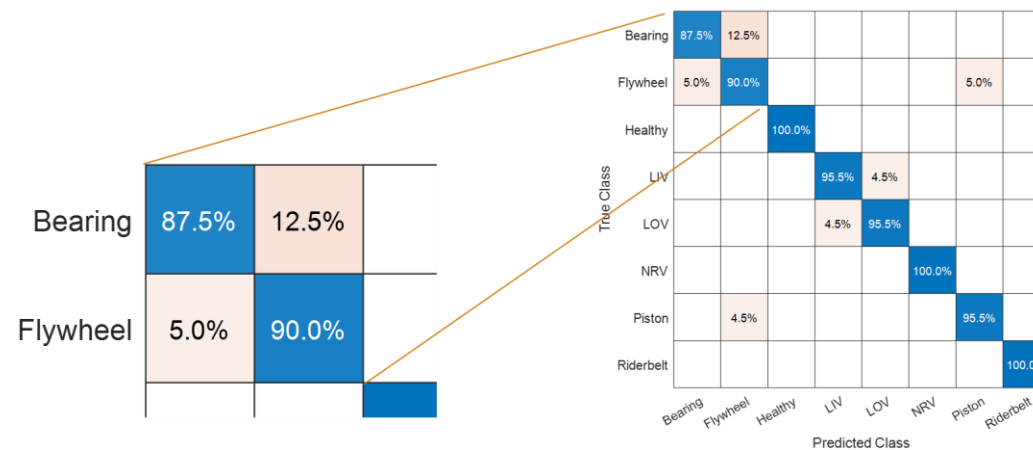
训练迭代

Deep Learning Toolbox - LSTM

Long Short Term Memory (LSTM) Networks



```
layers = [ ...
    sequenceInputLayer(size(trainingFeatures{1},1))
    lstmLayer(100,"OutputMode","sequence")
    dropoutLayer(0.1)
    lstmLayer(100,"OutputMode","last")
    fullyConnectedLayer(8)
    softmaxLayer
    classificationLayer];
```



部署



嵌入式设备



企业系统集成

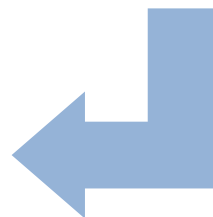
桌面应用, 边缘
设备, 云

MATLAB Coder – ARM

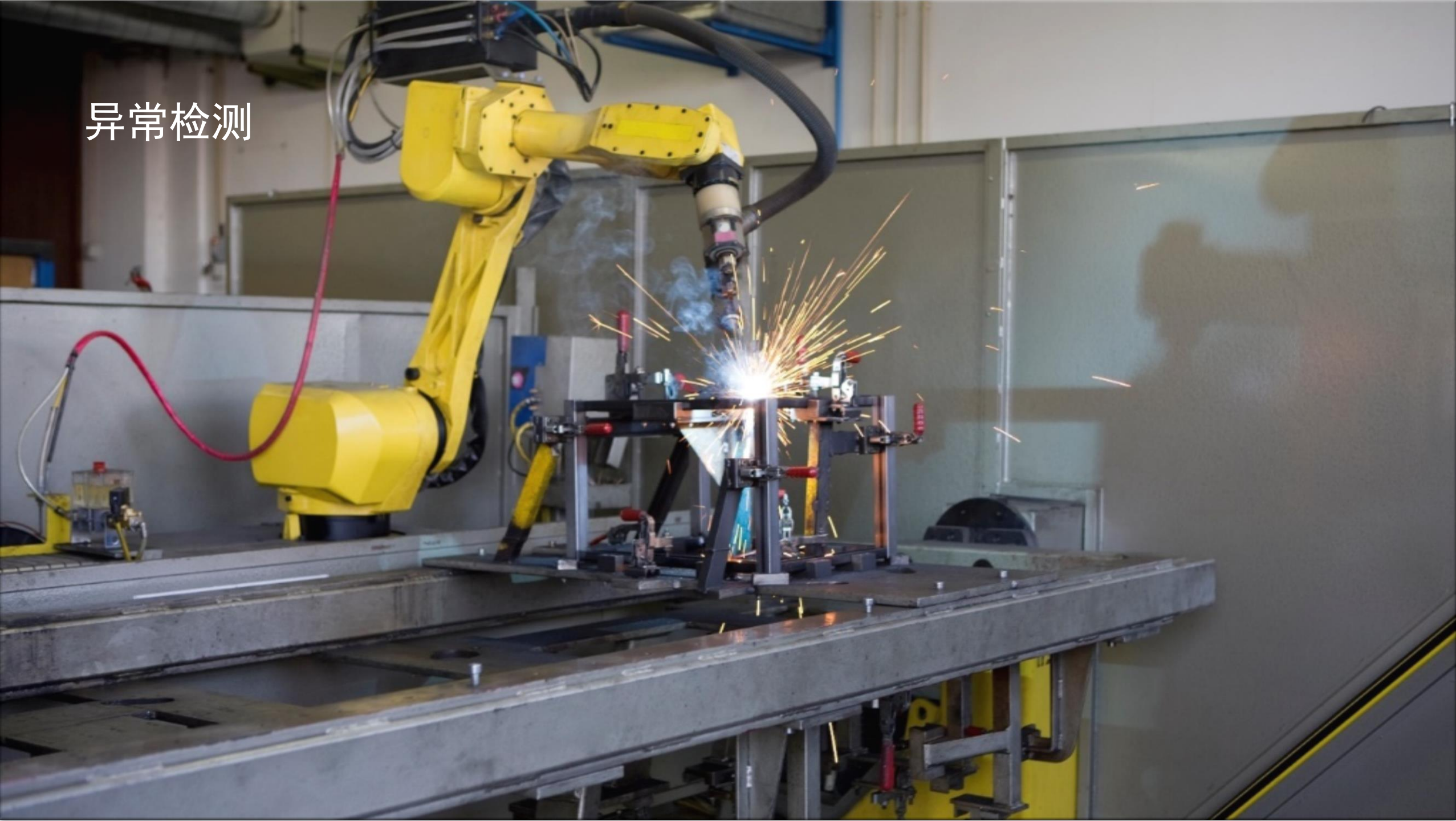
Generate Code for ARM Cortex-A

```
cfg = coder.config('lib');
cfg.GenCodeOnly = true;
cfg.GenerateMakefile = false;
cfg.TargetLang = 'C++';
dlcfg = coder.DeepLearningConfig('arm-compute');
dlcfg.ArmArchitecture = 'armv7';
dlcfg.ArmComputeVersion = '19.02';
cfg.DeepLearningConfig = dlcfg;
cfg.HardwareImplementation.ProdHWDeviceType = 'ARM Compatible->ARM Cortex';

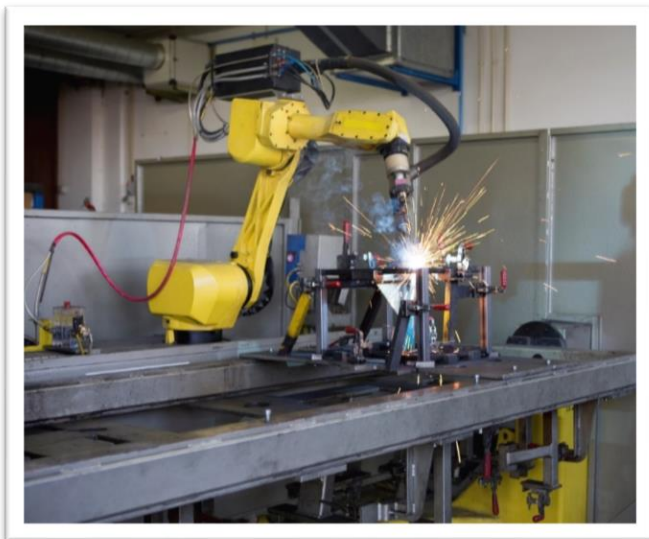
codegen -config cfg streamingClassifier -args...
        {single(ones(512,1)),single(ones(1,10)),single(ones(1,10))} -d arm_compute -report
```



异常检测



面临的情况



- 设备定期维护
- 故障发生次数较少，甚至没有
- 故障发生时后果严重



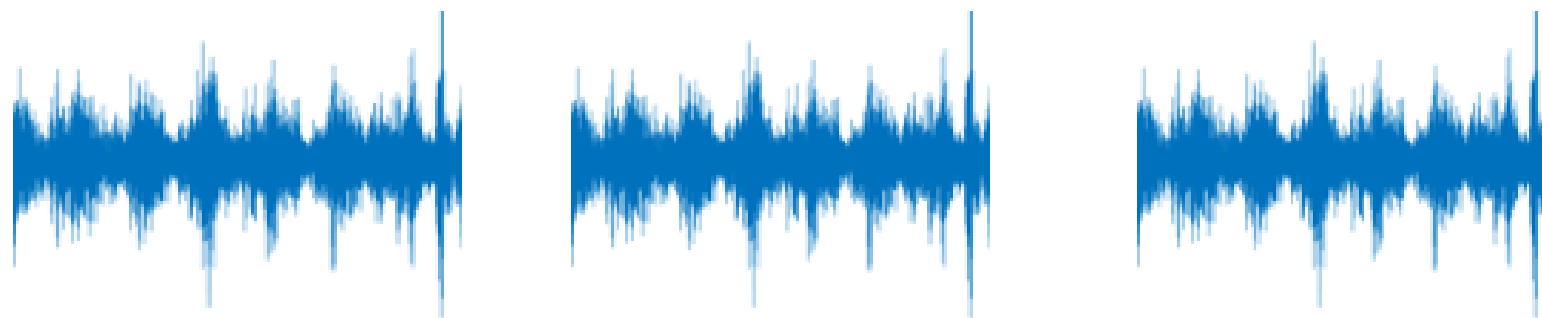
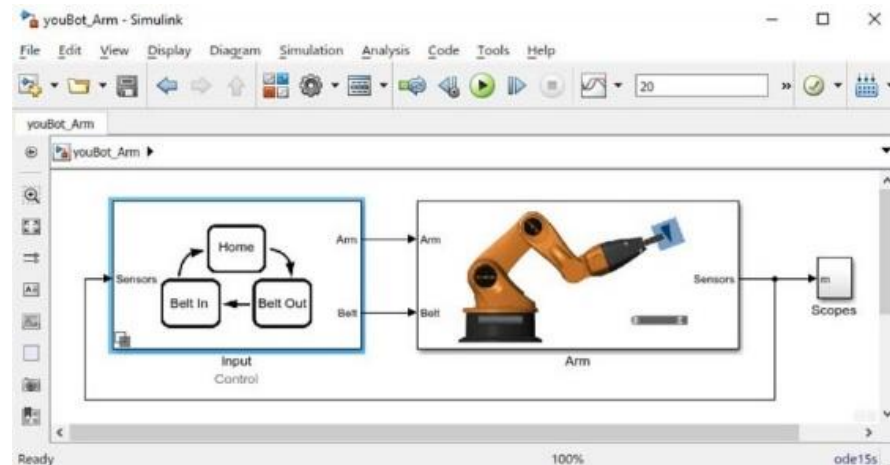
没有数据怎么办？

只有正常数据，没有故障数据怎么办？

故障诊断

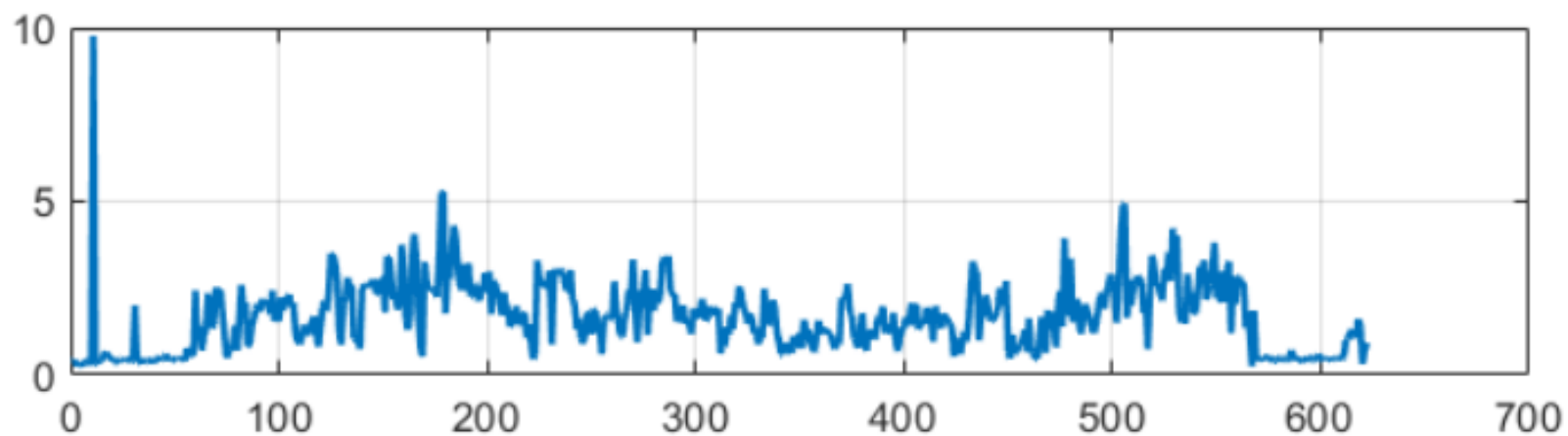
- 构建物理对象的仿真模型
- 仿真模型生成正常数据
- 通过故障注入，仿真模型产生故障数据
- 对数据进行标注

Simulink, Simscape



异常检测

- 根据设备正常运行数据训练模型
- 根据设备正常运行数据检测故障
- 异于正常情况的数据视为故障
- 避免预料外的问题，在严重故障出现前解决问题以规避风险



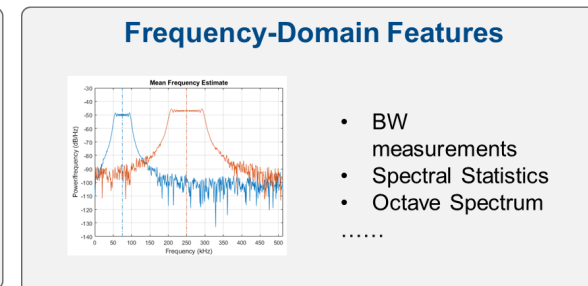
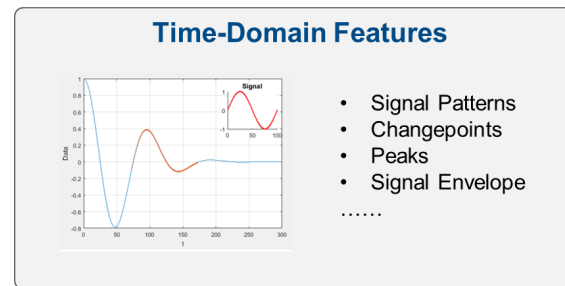
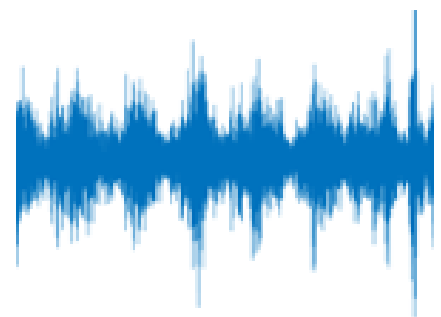
数据准备

Predictive Maintenance Toolbox – 特征提取

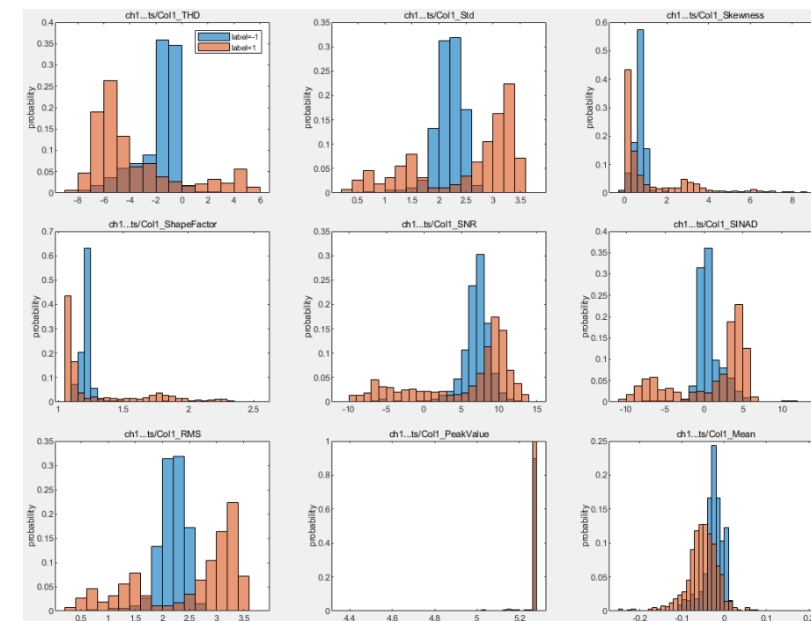
数据清洗

基于领域知识的数据处理

仿真数据补充



	1	2	3	4	5	6	7	8	9	10
1	-1.7327	0.6736	-0.2549	-1.5637	1.6215	3.0901	-2.2351	3.4670	0.9090	-2.1155
2	-0.6945	-0.4338	0.5131	-0.4466	1.5556	0.2420	-0.4189	0.8727	-0.0454	-0.5248
3	-0.5121	1.9210	0.5216	-1.3213	-0.2902	-0.0543	-0.5145	0.1455	-0.2633	-0.0819
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5	0.6505	1.4595	0.4353	-0.2087	0.3480	-0.2585	1.4928	-0.6599	0.4925	1.6933
6	-0.9904	2.2094	0.5543	-1.9034	-0.7336	0.1350	-0.6101	0.9072	-0.1250	-0.5624
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9	-0.2130	-0.0888	0.3596	0.1107	-0.5436	-0.1146	0.5370	-0.0191	0.7044	0.0562



AI建模



模型设计和参数设定

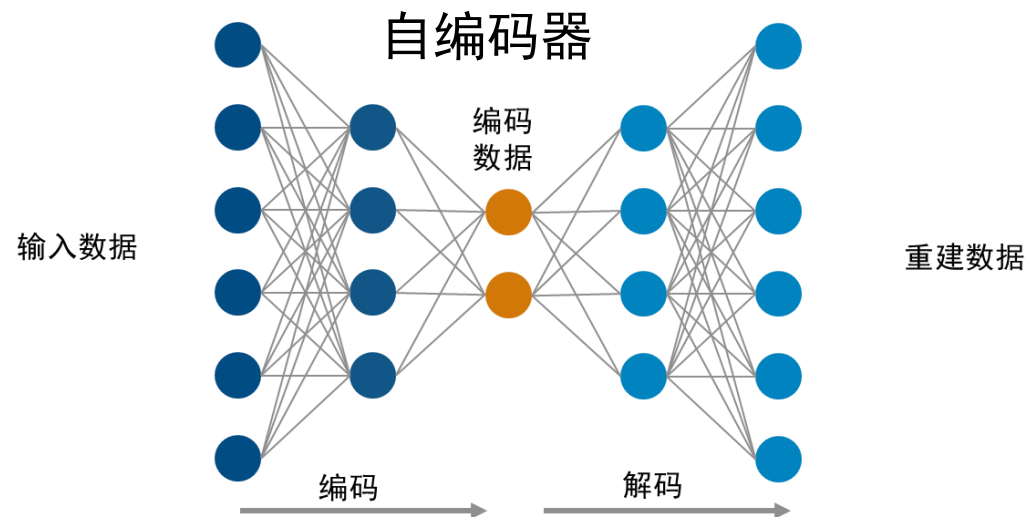
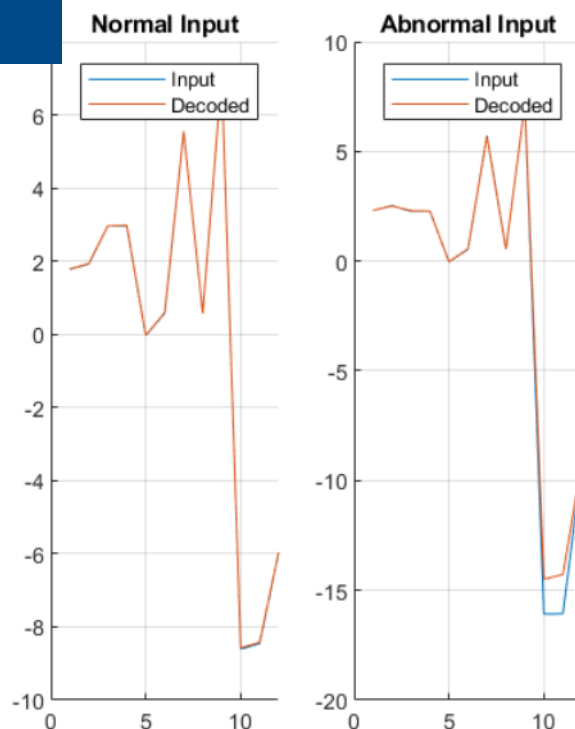


硬件加速



训练迭代

Deep Learning Toolbox – LSTM Based Autoencoder



```
layers = [ sequenceInputLayer(featureDimension, 'Name', 'in')
  bilstmLayer(16, 'Name', 'bilstm1')
  reluLayer('Name', 'relu1')
  bilstmLayer(32, 'Name', 'bilstm2')
  reluLayer('Name', 'relu2')
  bilstmLayer(16, 'Name', 'bilstm3')
  reluLayer('Name', 'relu3')
  fullyConnectedLayer(featureDimension, 'Name', 'fc')
  regressionLayer('Name', 'out') ];

net = trainNetwork(X, X, layers, options);
```

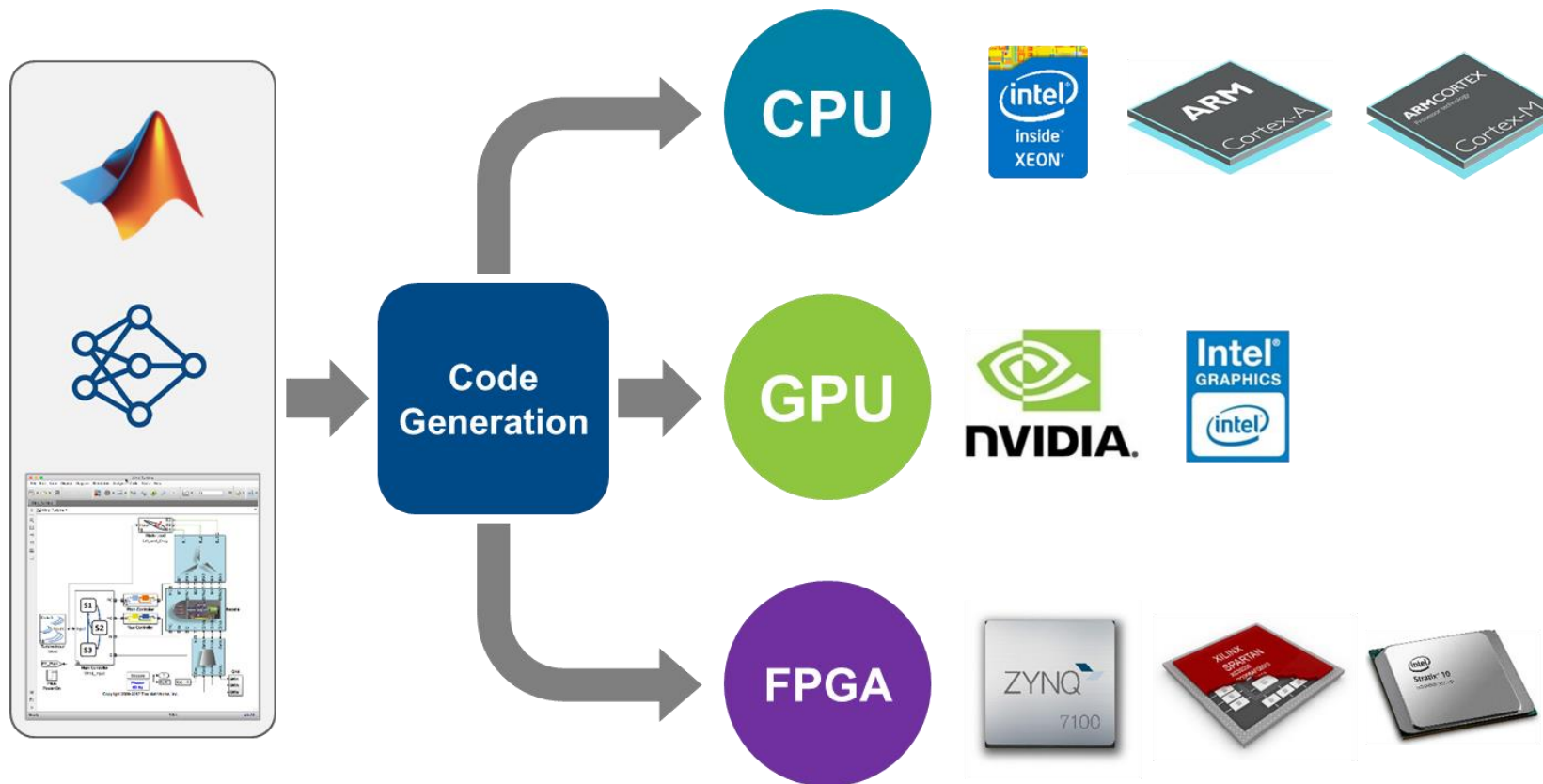
部署

 嵌入式设备

 企业系统集成

 桌面应用, 边缘设备, 云

MATLAB Coder
GPU Coder
HDL Coder



MATLAB EXPO 2021

谢谢！

