

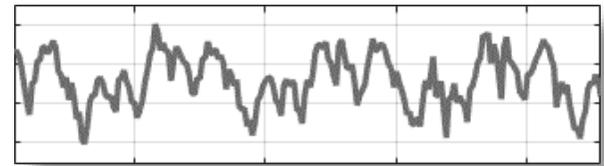
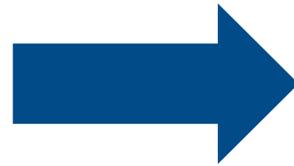
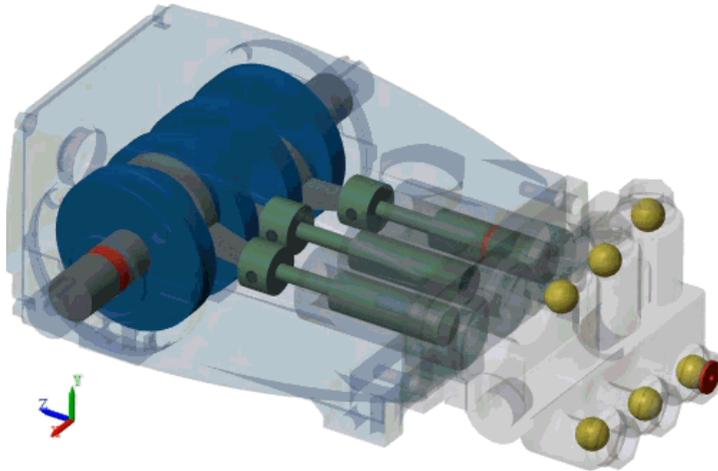
MATLAB EXPO 2019

智能运维：
预测性维护系统的研发

陈建平



预测性维护是什么？



文字

文档

点击图标下载 App

Android

iOS

检测语言

英语

中文

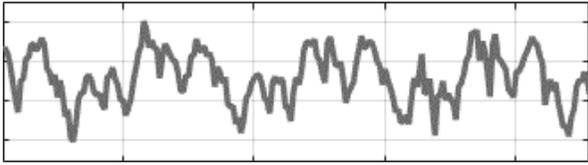
泵 - 检测信号



中文(简体)

英语

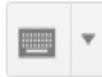
日语



求助!



0/5000



文字

文档

点击图标下载 App

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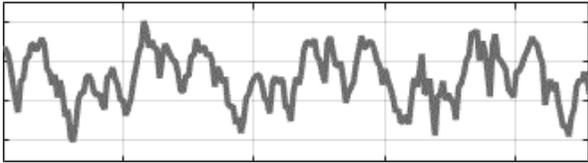
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中文(简体)

英语

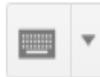
日语



求助！
我的一个气缸被堵住了。
我要在15个小时内关闭线路！



0/5000



预测性维护算法将回答一下问题

我的机器工作正常
吗？

异常检测

为什么我的机器行
为异常？

工况检测

我的机器还能工作
多久？

剩余使用
寿命估计

求助！

我的一个气缸被堵住了。

我要在15个小时内关闭线路！

预测性维护工具箱

我的机器工作正常
吗？

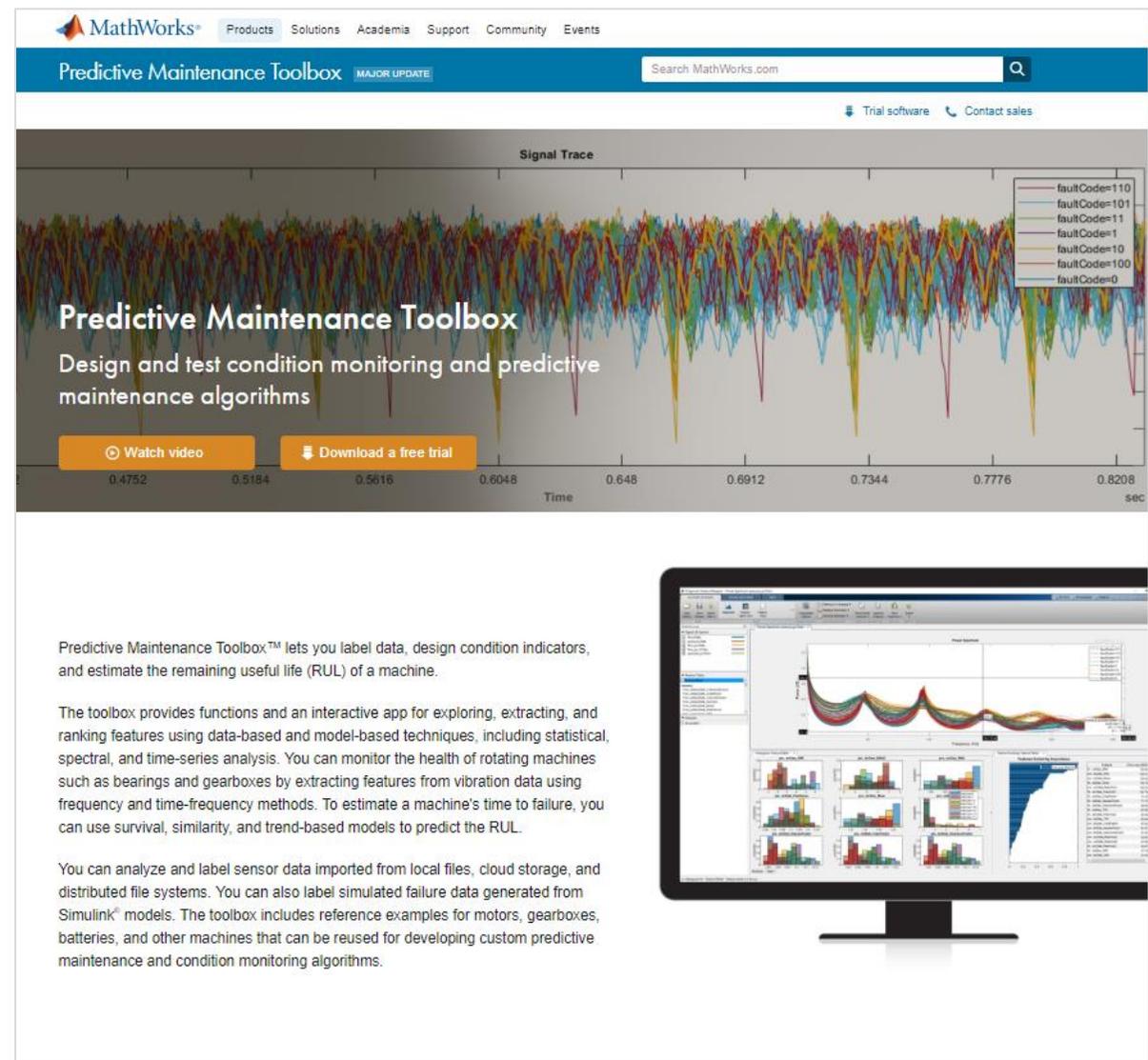
异常检测

为什么我的机器行
为异常？

工况检测

我的机器还能工作
多久？

剩余使用
寿命估计



Predictive Maintenance Toolbox MAJOR UPDATE

Search MathWorks.com

Trial software Contact sales

Signal Trace

Predictive Maintenance Toolbox
Design and test condition monitoring and predictive maintenance algorithms

Watch video Download a free trial

Predictive Maintenance Toolbox™ lets you label data, design condition indicators, and estimate the remaining useful life (RUL) of a machine.

The toolbox provides functions and an interactive app for exploring, extracting, and ranking features using data-based and model-based techniques, including statistical, spectral, and time-series analysis. You can monitor the health of rotating machines such as bearings and gearboxes by extracting features from vibration data using frequency and time-frequency methods. To estimate a machine's time to failure, you can use survival, similarity, and trend-based models to predict the RUL.

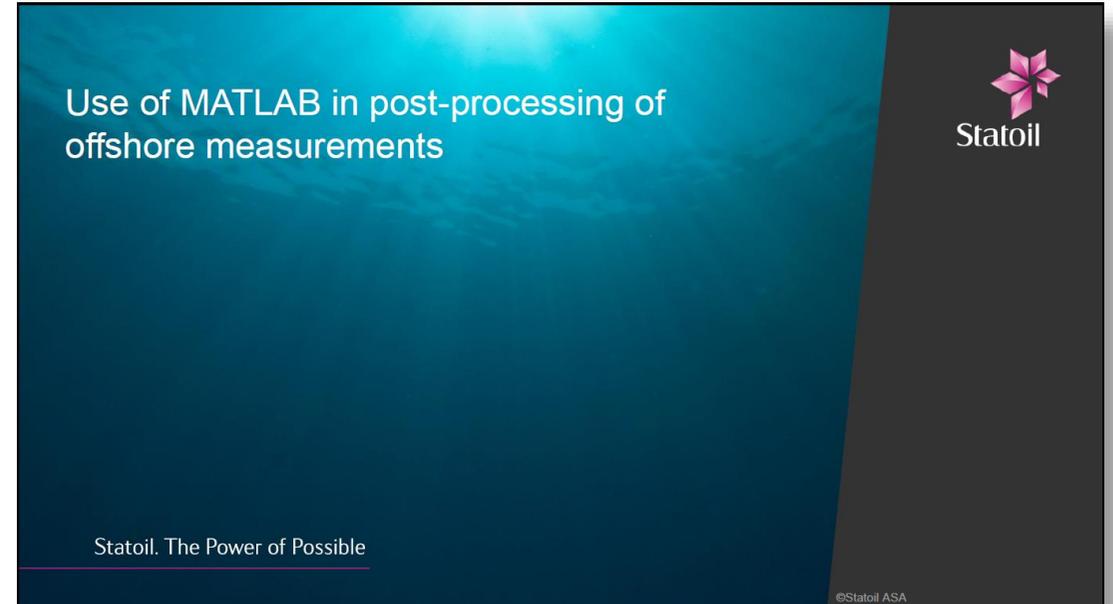
You can analyze and label sensor data imported from local files, cloud storage, and distributed file systems. You can also label simulated failure data generated from Simulink® models. The toolbox includes reference examples for motors, gearboxes, batteries, and other machines that can be reused for developing custom predictive maintenance and condition monitoring algorithms.

预测性维护成功案例



[Link to user story](#)

“...Subject Matter Expert Familiarity...”



[Link to user story](#)

“... [MATLAB is] Popular across the company...”

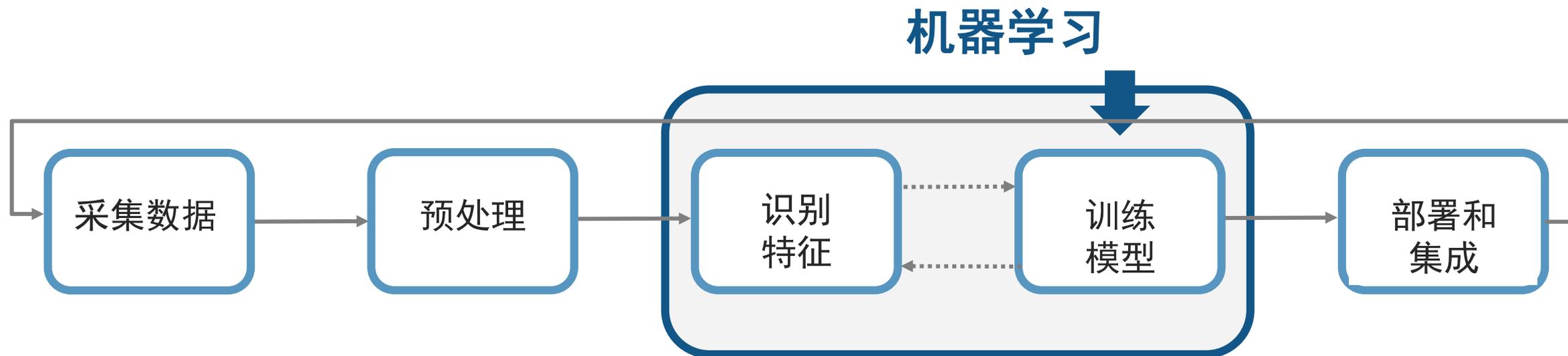


Mercedes-Benz



BOSCH

开发预测性维护算法的流程

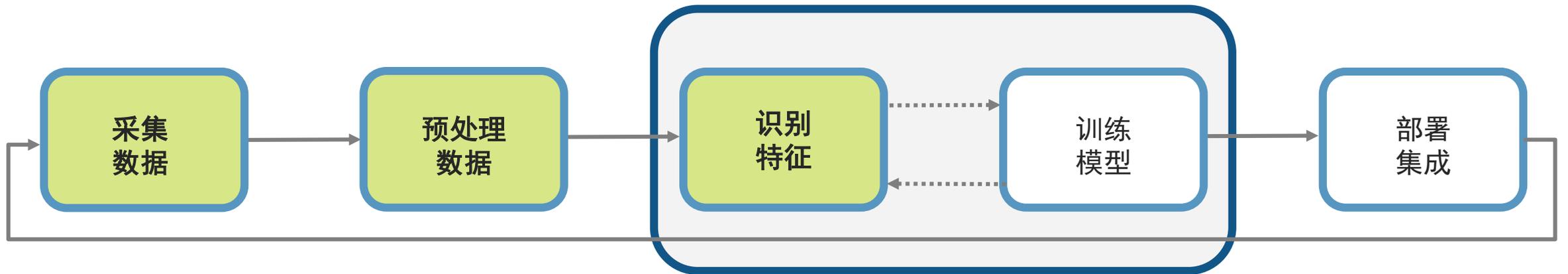


MATLAB & Simulink 开发预测性维护系统的优势

- 减少存储和传输所需的数据量
- 探索特征提取和预测性建模的方法
- 依据你的目标客户提供分析结果
- 快速起步.....

MATLAB & Simulink 开发预测性维护系统的优势

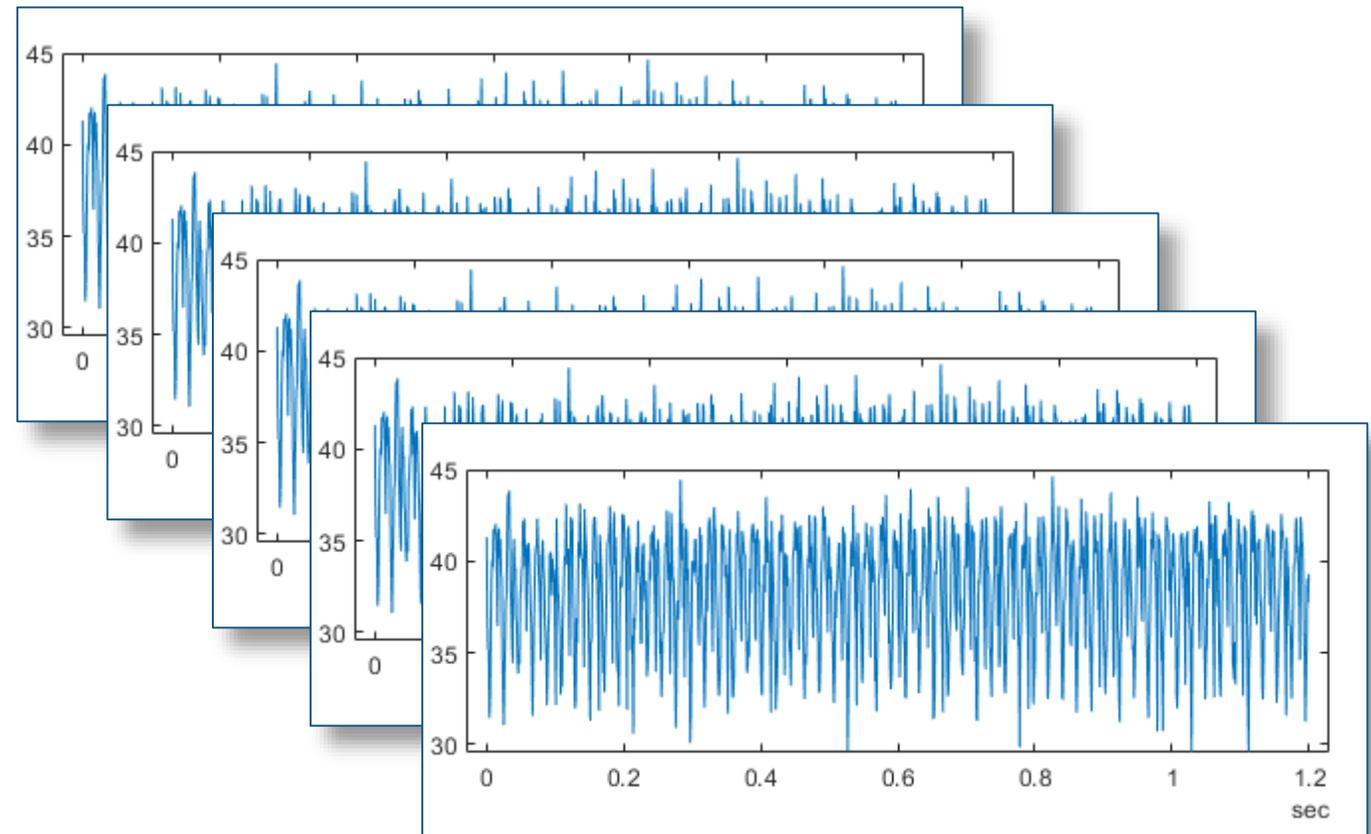
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- 依据你的目标客户提供分析结果
- 快速起步.....



挑战：如何深刻理解所收集的所有数据？

- 1 天 ~ 1.3 GB
- 20 个传感器/泵 ~26 GB/天
- 3 个泵 ~ 78 GB/天
- 卫星传输
 - 传输速度：128-150 kbps,
 - 花费 \$1,000/10GB
- 大海捞针

Pump flow sensor 1 sec ~ 1000 samples ~16kB



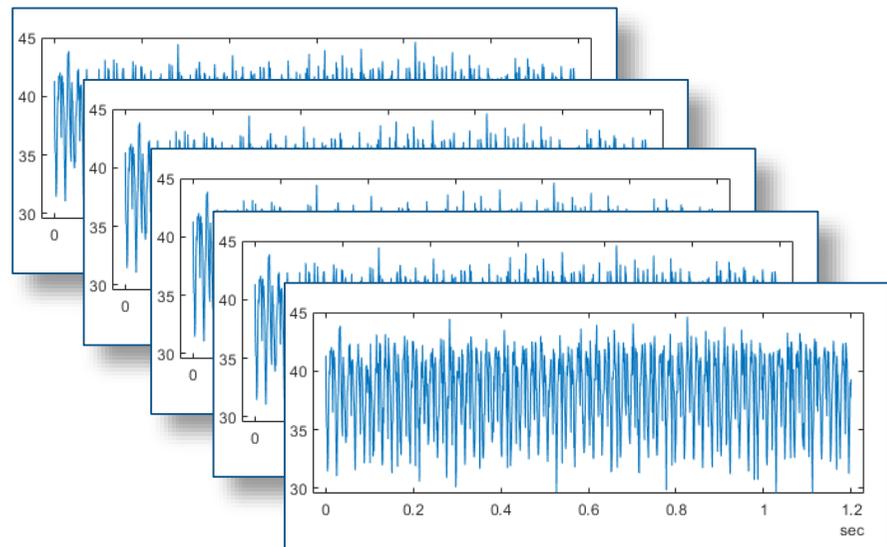
解决方案: 特征提取

减少存储和传输所需的数据量

- 如何提取特征?
 - 信号处理的方法
 - 统计和基于模型的方法

- 需要提取哪些特征?
 - 基于可用数据
 - 基于可用硬件

- 如何处理流数据?
 - 确定缓冲大小
 - 通过缓冲滑动窗口提取特征

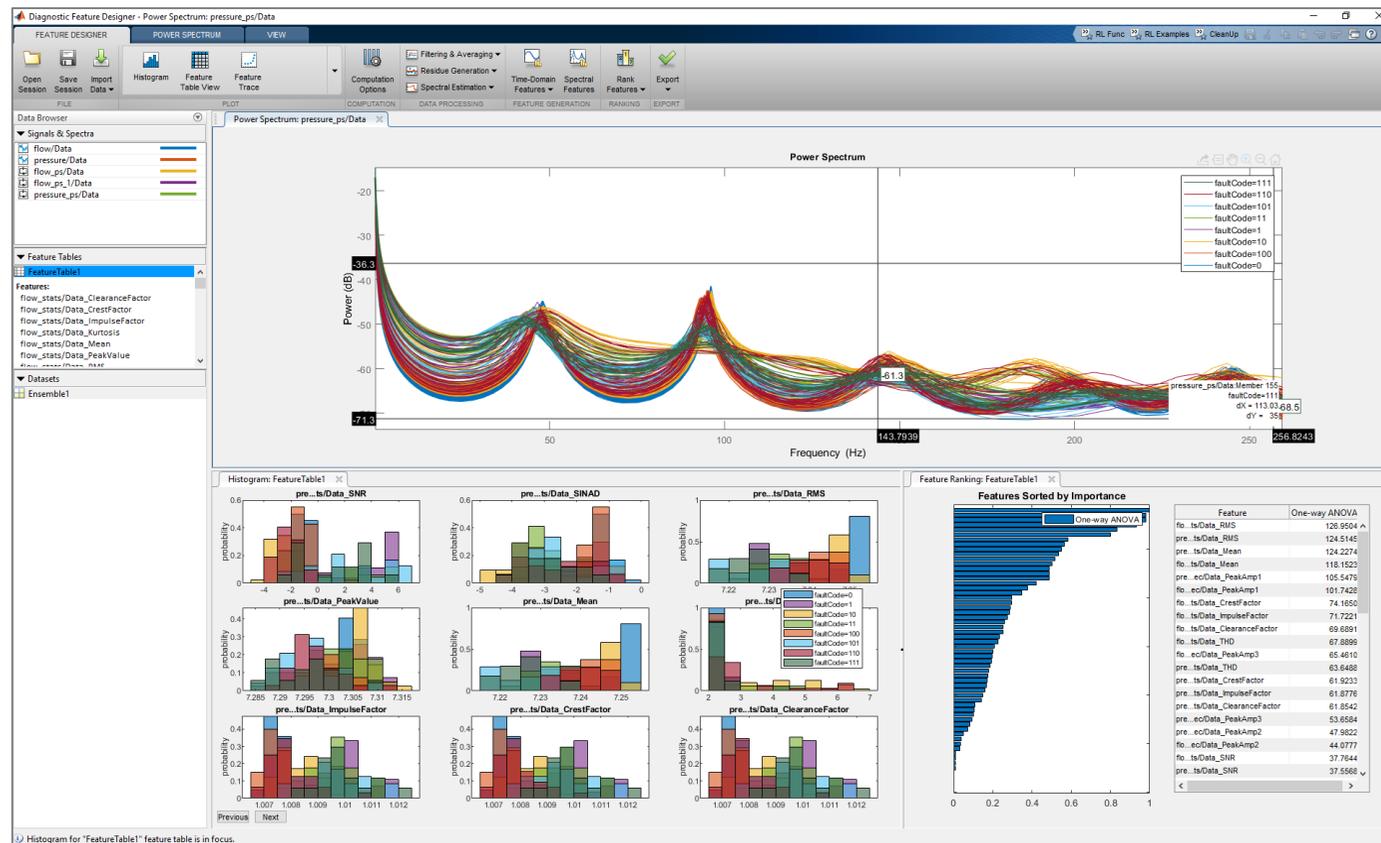


qMean	qVar	qSkewness	qKurtosis
38.4945	9.2306	-0.5728	2.4662
qPeak2P...	qCrest	qRMS	qMAD
15.2351	1.1553	38.6141	2.5562

Diagnostic Feature Designer App

预测性维护工具箱 R2019a

- 从传感信号中提取特征、可视化和重要性排序
- 可以使用统计和动态建模方法
- 处理超过内存量的大数据
- 无需写 MATLAB 代码，实现特征探索和发现



FEATURE DESIGNER | SIGNAL TRACE | VIEW

Open Session | Save Session | Import Data

Signal Trace

Computation Options

Filtering & Averaging | Residue Generation | Spectral Estimation

Time-Domain Features | Spectral Features

Rank Features | Export

FILE | PLOT | COMPUTATION | DATA PROCESSING | FEATURE GENERATION | RANKING | EXPORT

Data Browser

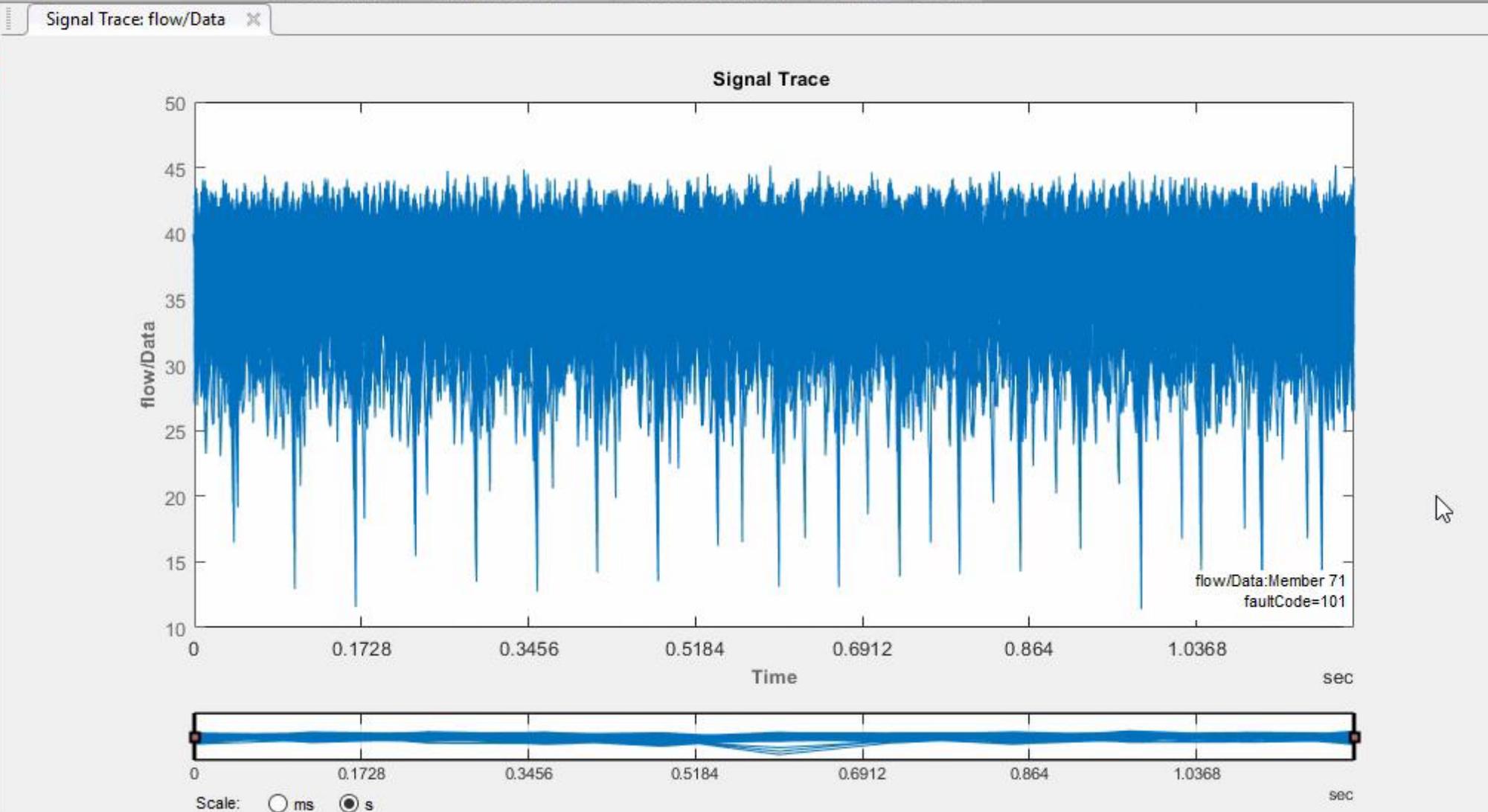
▼ Signals & Spectra

- flow/Data
- pressure/Data

▼ Feature Tables

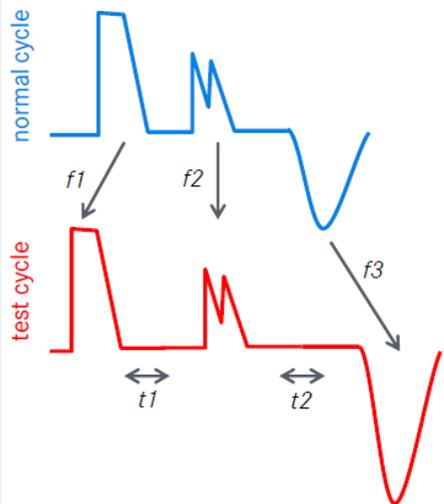
▼ Datasets

- Ensemble1



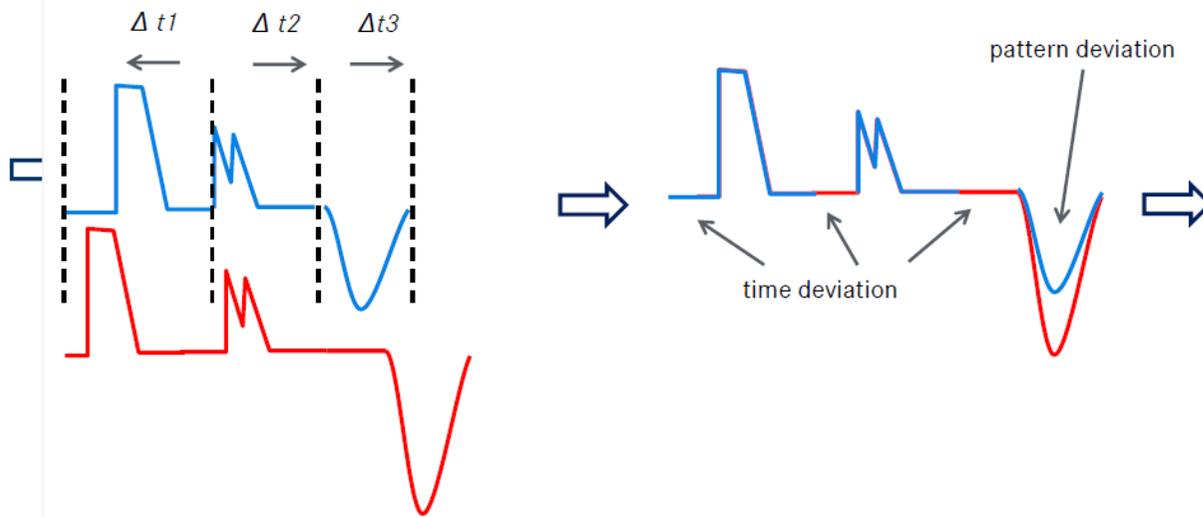
戴姆勒正在使用 MATLAB 进行异常检测

Algorithm principle



- Cycle can be described as sequence features f_1, f_2, f_3
- Each cycle can show some delays in time t_1, t_2

Algorithm principle



- Pattern matching through shift of feature along time axis ($\Delta t_1, \Delta t_2, \Delta t_3$): minimization of SRS

- Description of a cycle as feature sequence
- For each feature time and pattern deviation can be calculated

f_1	f_2	f_3	
Δt_1	Δt_2	Δt_3	Time deviation
No	No	Yes	Pattern deviation

- Time and pattern deviation for each feature are used as characteristic numbers for test cycle

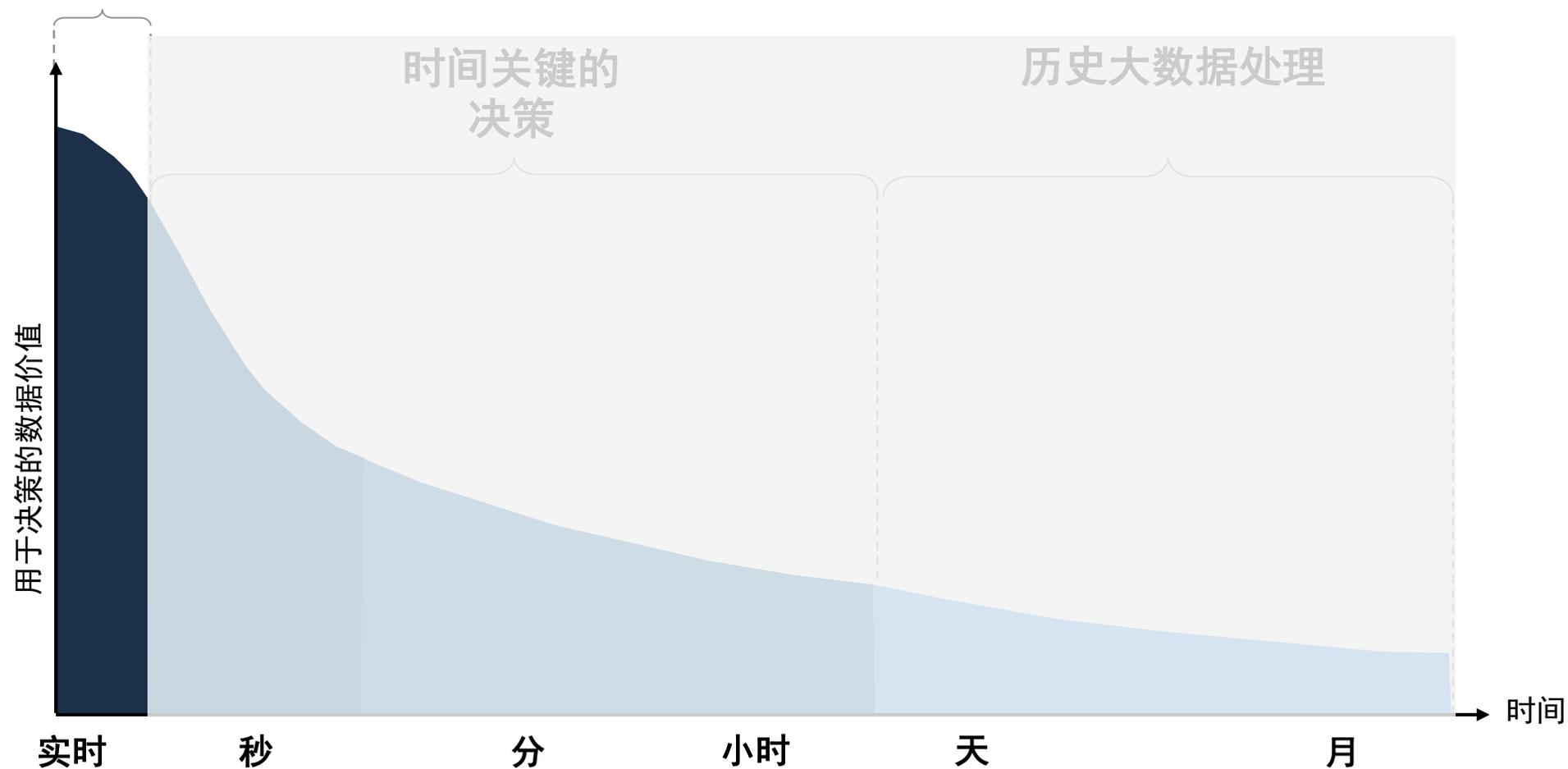


Data reduction!

数据减少**250倍**而没有明显的信息丢失

你的数据什么时候最有价值？

近实时决策



FILE NAVIGATE EDIT BREAKPOINTS RUN

New Open Save Find Files Compare Print Go To Find Insert Comment Indent Breakpoints Run Run and Advance Run Section Advance Run and Time

C:\Users\abaru\Desktop\Expo 2018\FinalDemo\Demo_Files\Data_Reduction

Current Folder

- Folder
 - codegen
 - Copy_of_Data
 - Data
- Function
 - featureExtraction.m
 - featureExtractionBuffer.m
 - helperSortedBarPlot.m
 - monotonicity.m
- MEX-file
 - featureExtraction_mex.mexw64
 - featureExtractionBuffer_mex.mexw64
- Live Script
 - Expo_Data_Preprocessing_CodeGe...
- MATLAB Code Project
 - featureExtraction.prj
 - featureExtractionBuffer.prj

featureExtractionBuffer.m (Function)

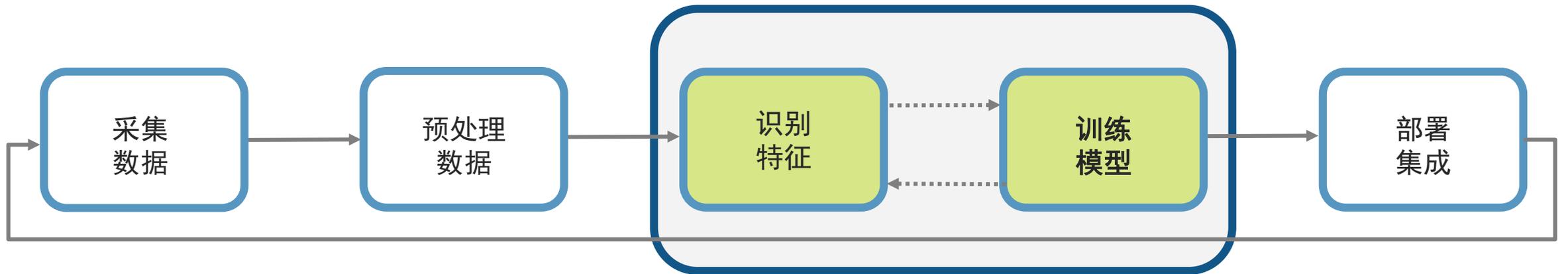
Editor - C:\Users\abaru\Desktop\Expo 2018\FinalDemo\Demo_Files\Data_Reduction\featureExtractionBuffer.m

Expo_Data_Preprocessing_CodeGen.mlx featureExtractionBuffer.m

```
1 function [feature_list] = featureExtractionBuffer(data,timestamp)
2
3 persistent flow_array
4 persistent time_array
5 Np = 1000;
6
7 if isempty(flow_array)
8     flow_array = nan(Np,1);
9 end
10
11 if isempty(time_array)
12     time_array = nan(Np,1);
13 end
14
15 flow_array = [data; flow_array(1:Np-1)];
16 data = flow_array;
17
18 time_array = [timestamp; time_array(1:Np-1)];
19 timestamp = time_array;
20
21
22 if isempty(find(isnan(data),1))
23
24     flow = data;
25
26     % Ensure the flow is sampled at a uniform sample rate
27     t_flow = timestamp;
```

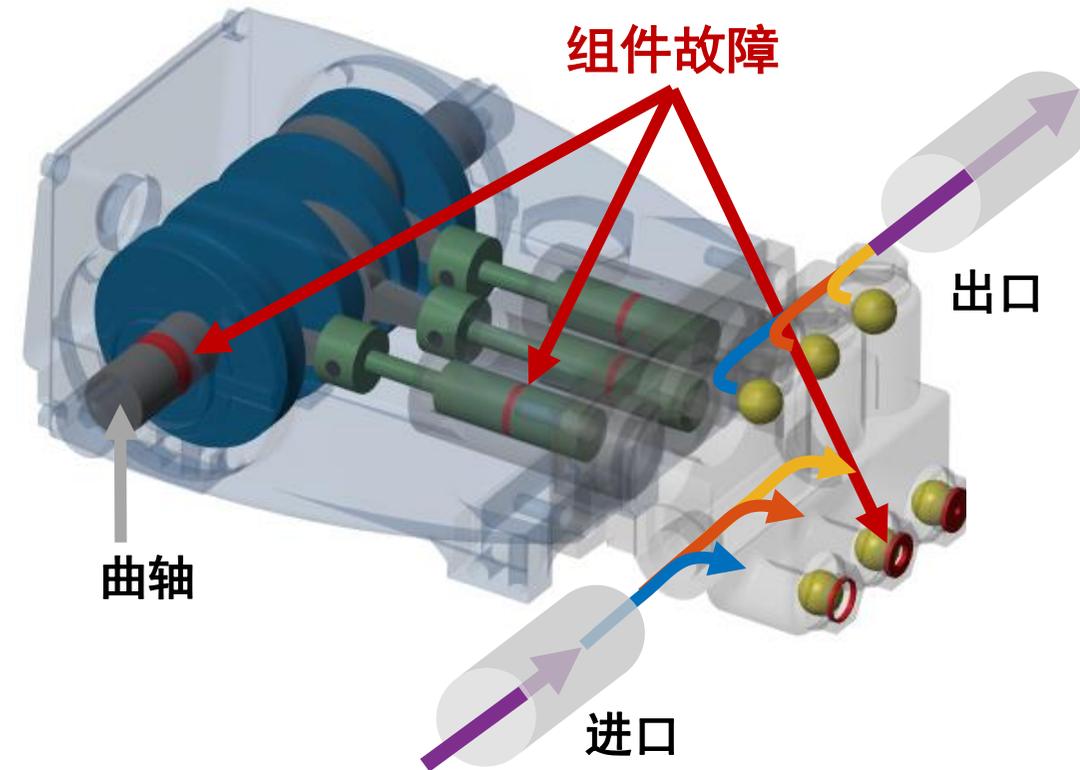
MATLAB & Simulink 开发预测性维护系统的优势

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- 探索特征提取和预测性建模的方法
- 依据你的目标客户提供分析结果
- 快速起步.....



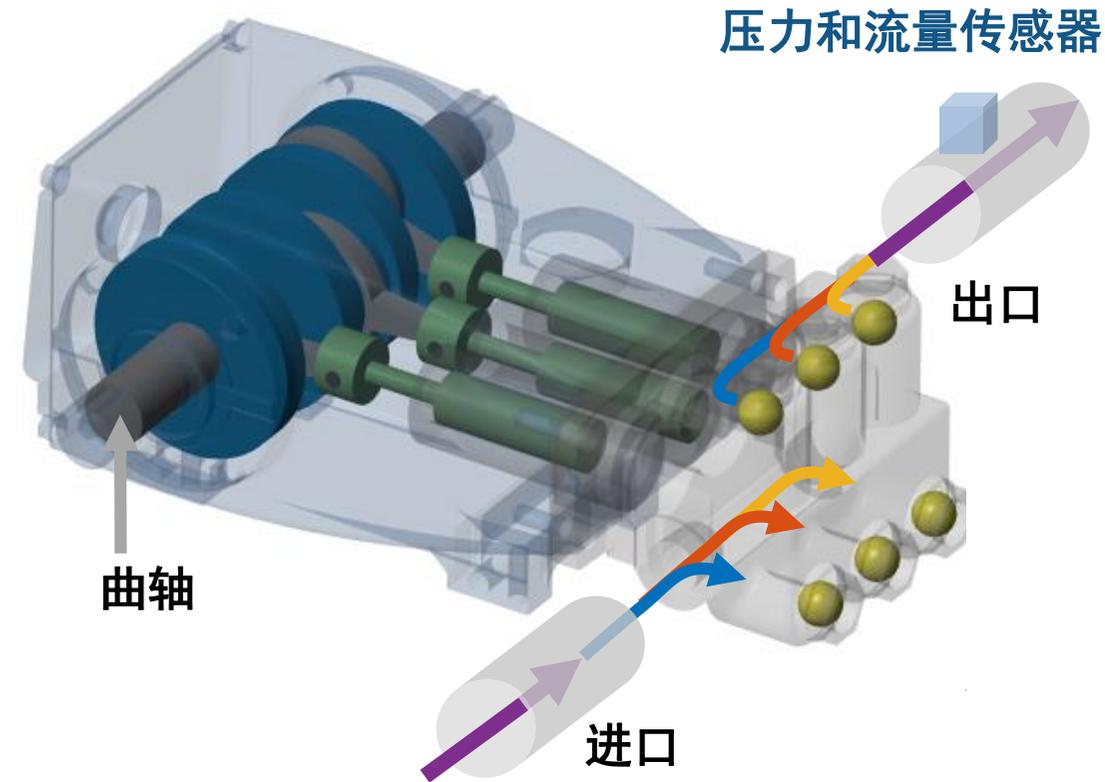
故障分类算法识别异常行为的根本原因

- 三相泵常用于钻井和提供油井服务
 - 三个柱塞试图确保均匀的流量
- 工况监测检测：
 - 密封泄露
 - 进口堵塞
 - 轴承损坏



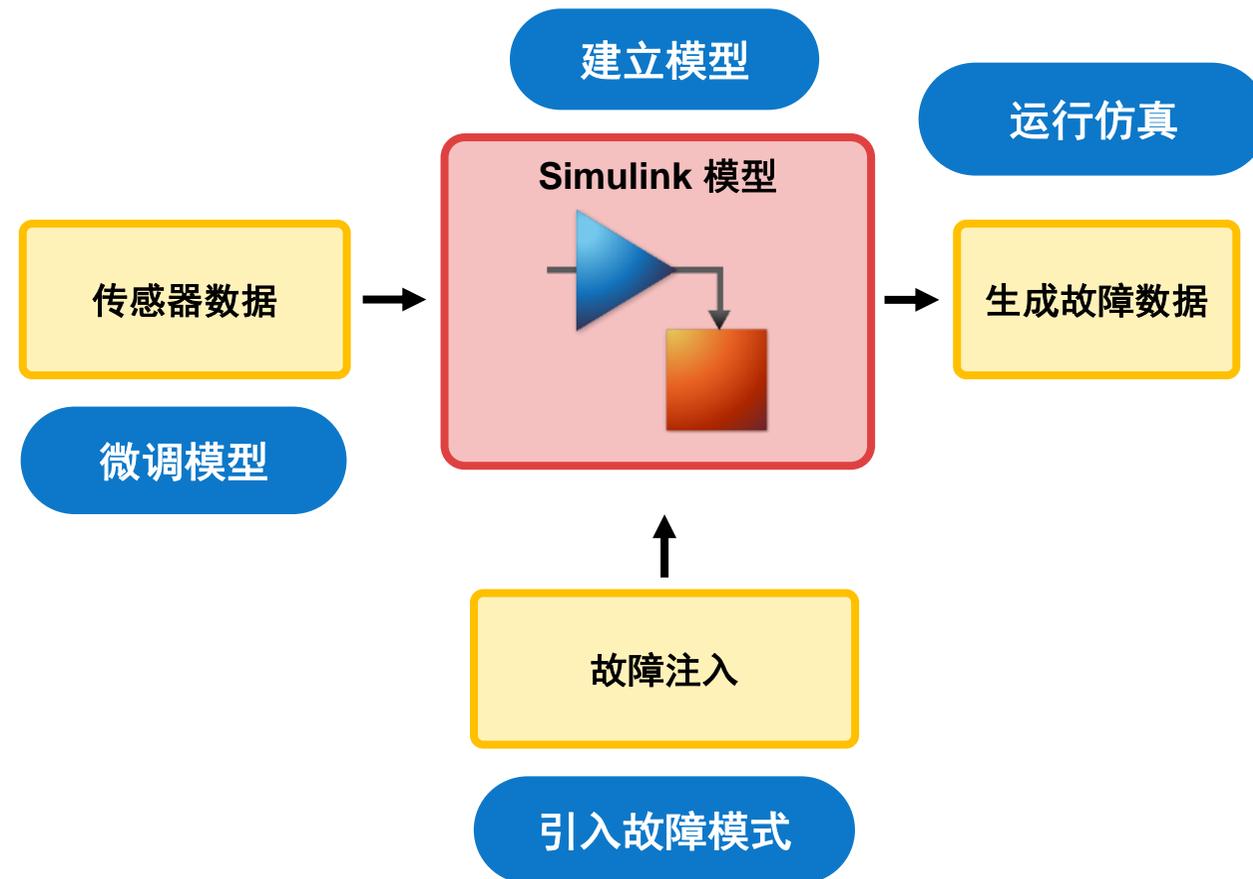
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- 工况监测检测：
 - 密封泄露
 - 进口堵塞
 - 轴承损坏
- 仅使用压力和流量传感器数据识别系统中存在的故障



当实际故障数据不可用，可以从 Simulink 模型合成故障数据

- 故障模式建模
 - 与领域专家和可用数据协作
 - 改变模型参数和组件
- 针对指定机器定制模型
 - 基于实际数据微调模型
 - 验证调整模型的性能



FEATURE DESIGNER | SIGNAL TRACE | VIEW

Open Session | Save Session | Import Data

Select data to plot

Signal Trace | Power Spectrum | Order Spectrum | Histogram

Filtering & Averaging | Residue Generation | Spectral Estimation

Computation Options

Time-Domain Features | Spectral Features | Rank Features | Export

FILE | PLOT | COMPUTATION | DATA PROCESSING | FEATURE GENERATION | RANKING | EXPORT

Data Browser

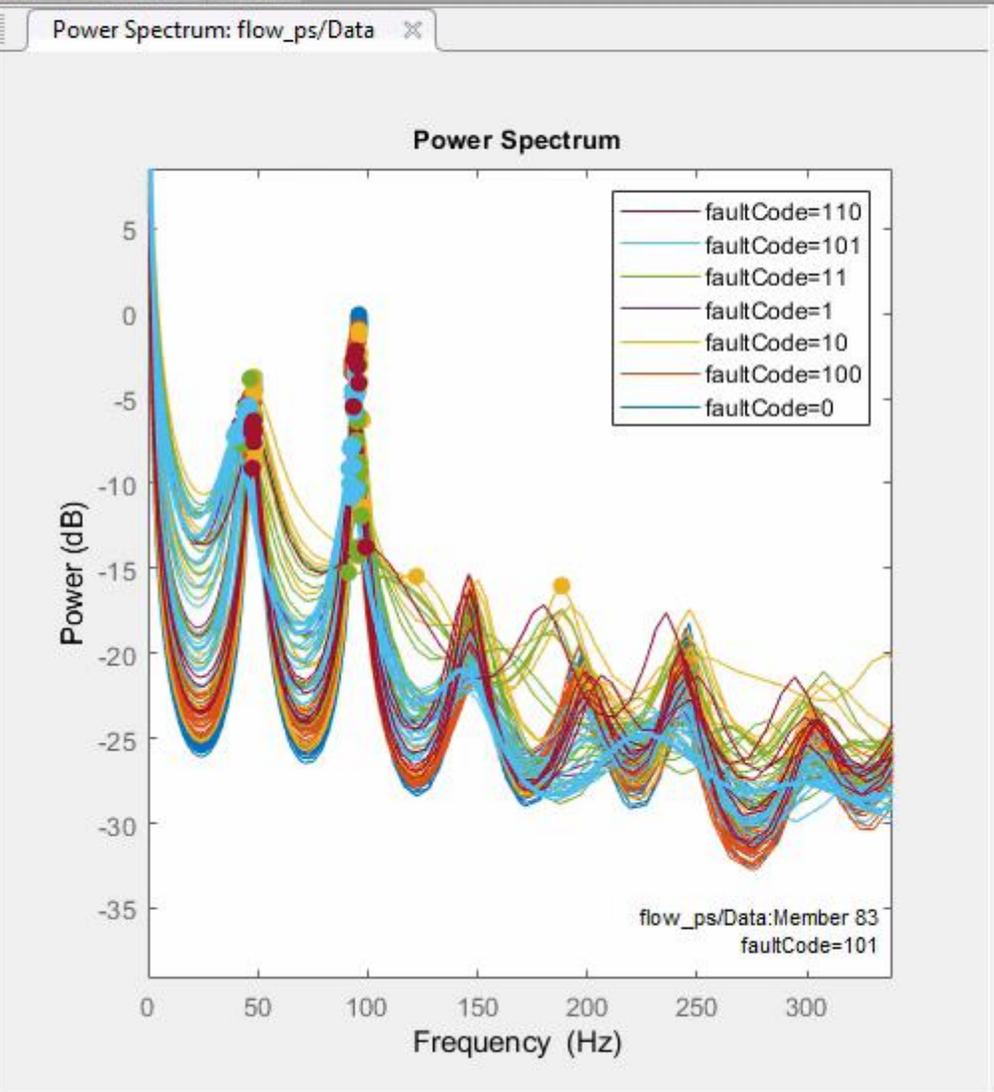
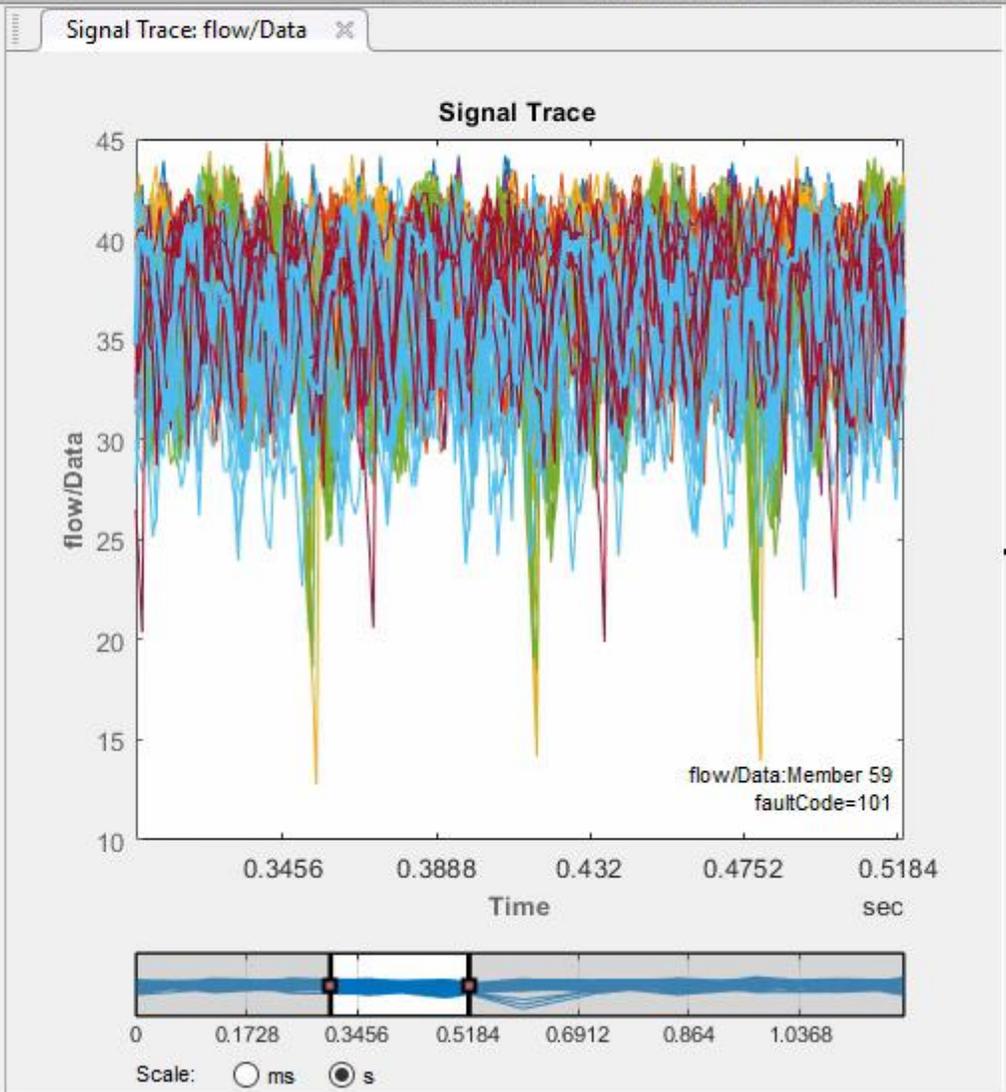
▼ Signals & Spectra

- flow/Data
- pressure/Data
- flow_ps/Data

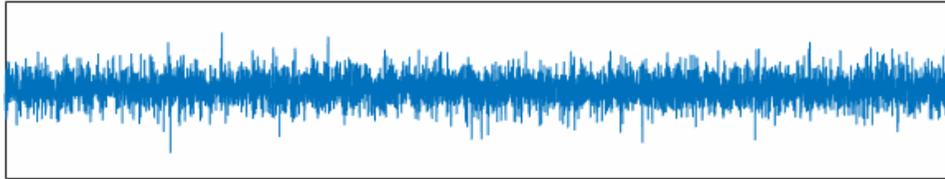
▼ Feature Tables

▼ Datasets

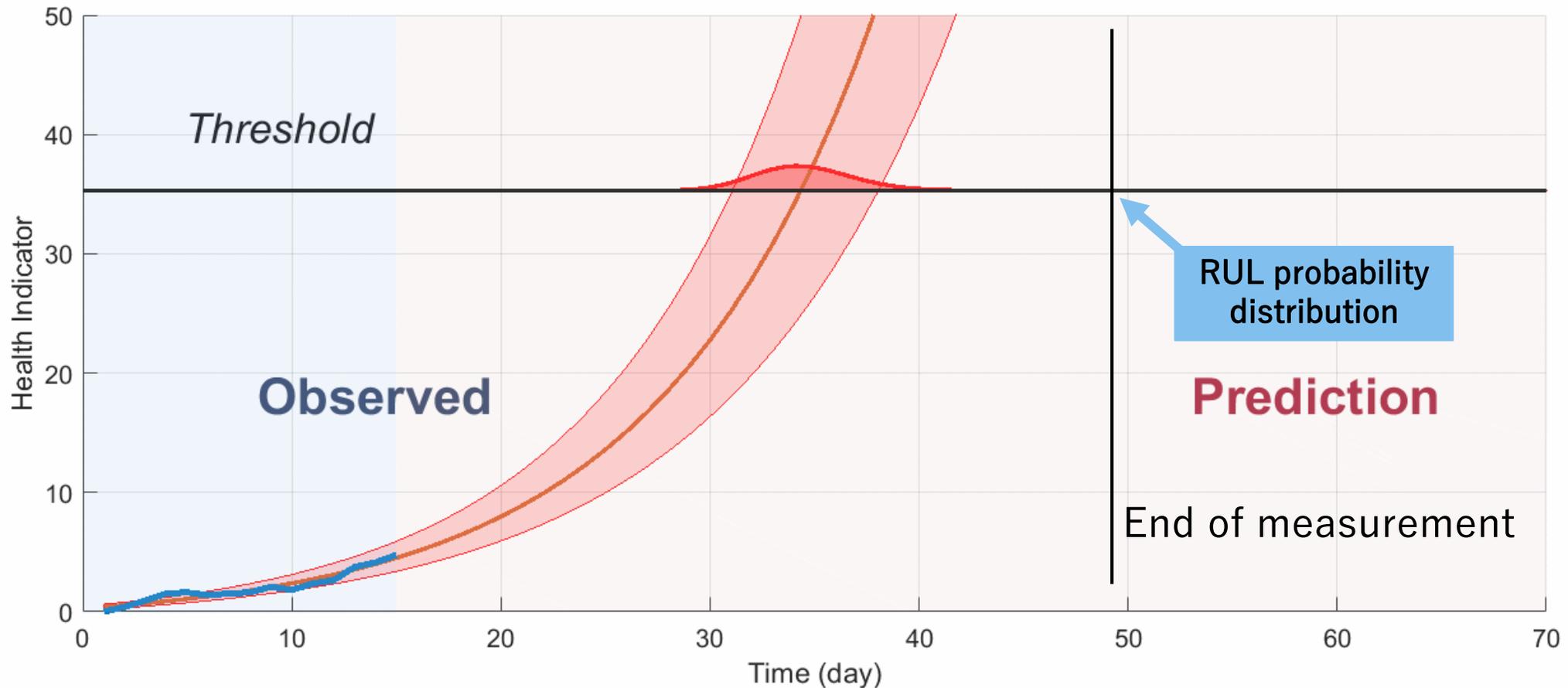
- Ensemble1



估计剩余使用寿命（RUL） 确定何时进行维护



RUL: 459 hours
(95%CI: 374-558 hours)



贝克休斯开发了用于天然气和石油开采的预测性维护软件

挑战

开发预测性维护系统，以降低泵设备成本和停机时间

解决方案

使用MATLAB分析近1TB的数据，并创建一个可以在故障发生之前预测故障的机器学习模型

成果

- 预计节省超过1000万美元
- 开发时间减少一个量级
- 轻松访问多种类型的数据



带正排量泵的卡车

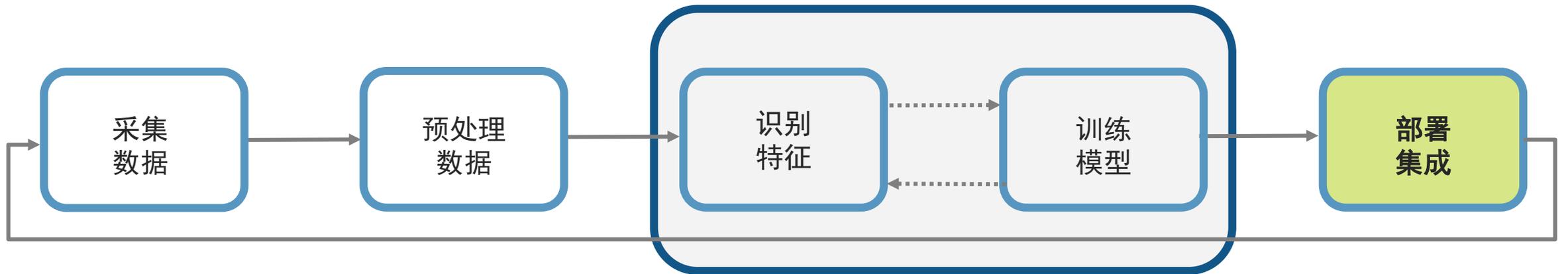
“MATLAB使我们能够将以前不可读的数据转换成可用的格式; 为多个卡车和地区自动化过滤, 频谱分析和转换步骤; 并最终实时应用机器学习技术来预测进行维护的理想时间。”

- Gulshan Singh, Baker Hughes

[Link to user story](#)

MATLAB & Simulink 开发预测性维护系统的优势

- 减少存储和传输所需的数据量
- 探索式特征提取和预测性建模
- 依据你的目标客户提供分析结果
- 快速起步.....

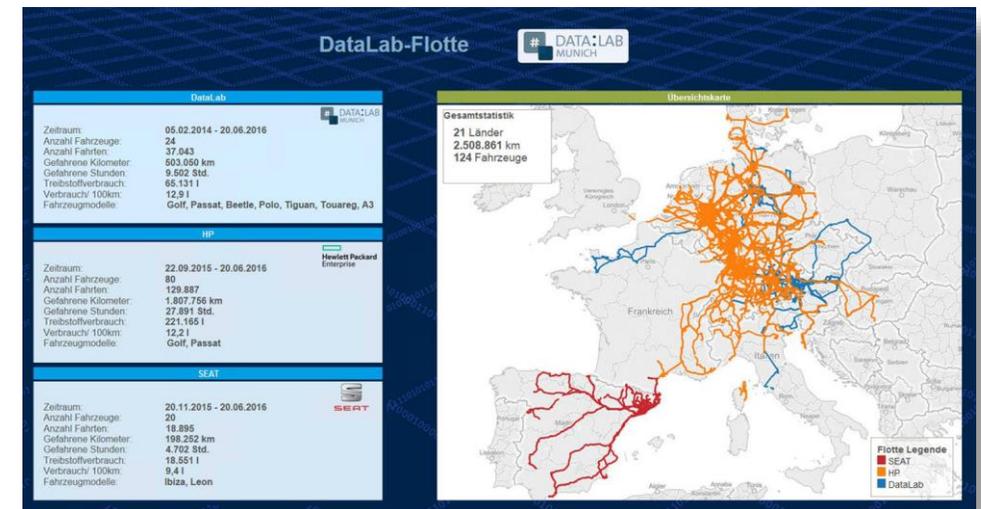


挑战：为最终用户提供结果

- 维护需要简单、快捷的信息
 - 手持设备，警告器
- 需要更高视角来执行操作
 - 和 IT 和 OT 系统集成
- 客户希望得到易于消化的信息
 - 自动报告

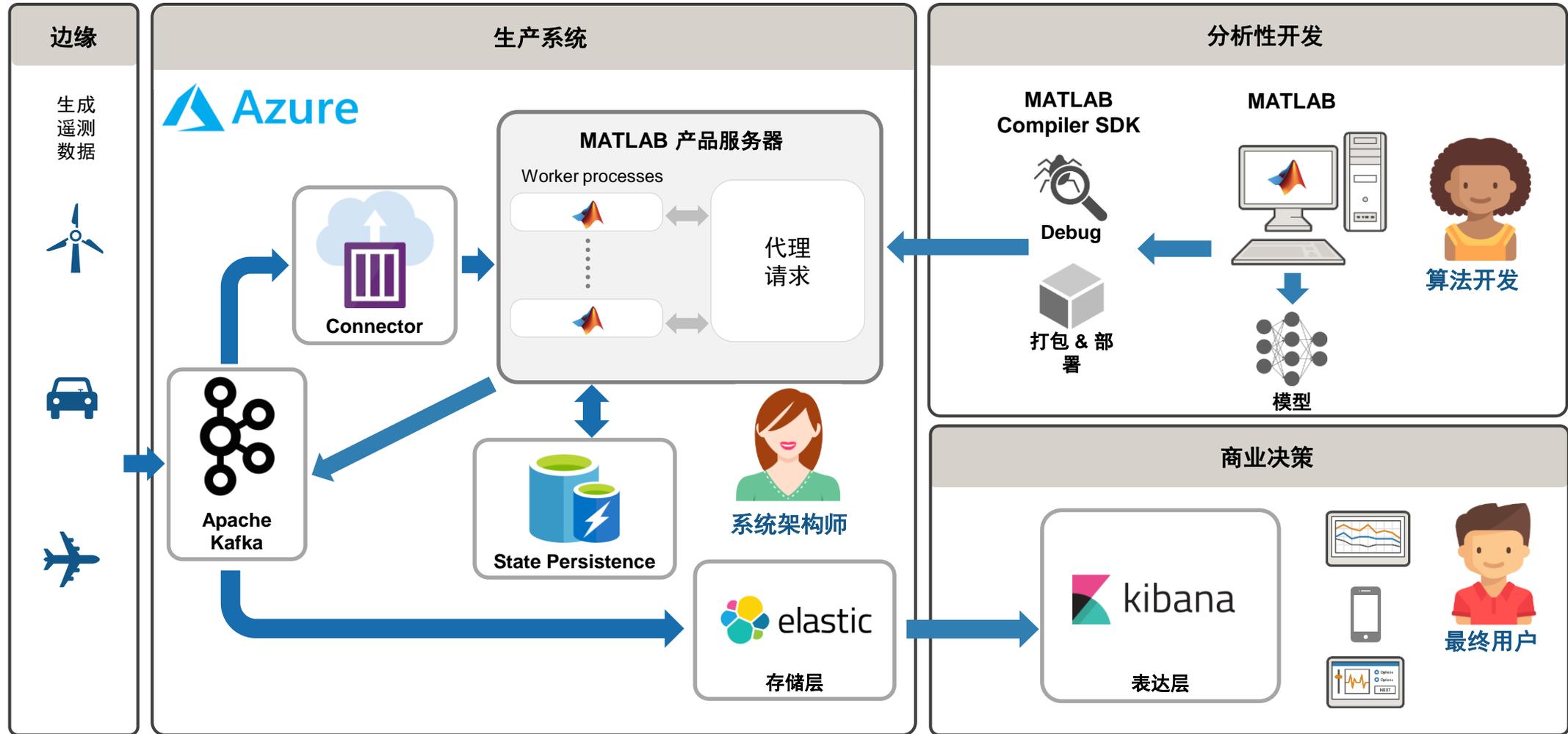


Dashboards

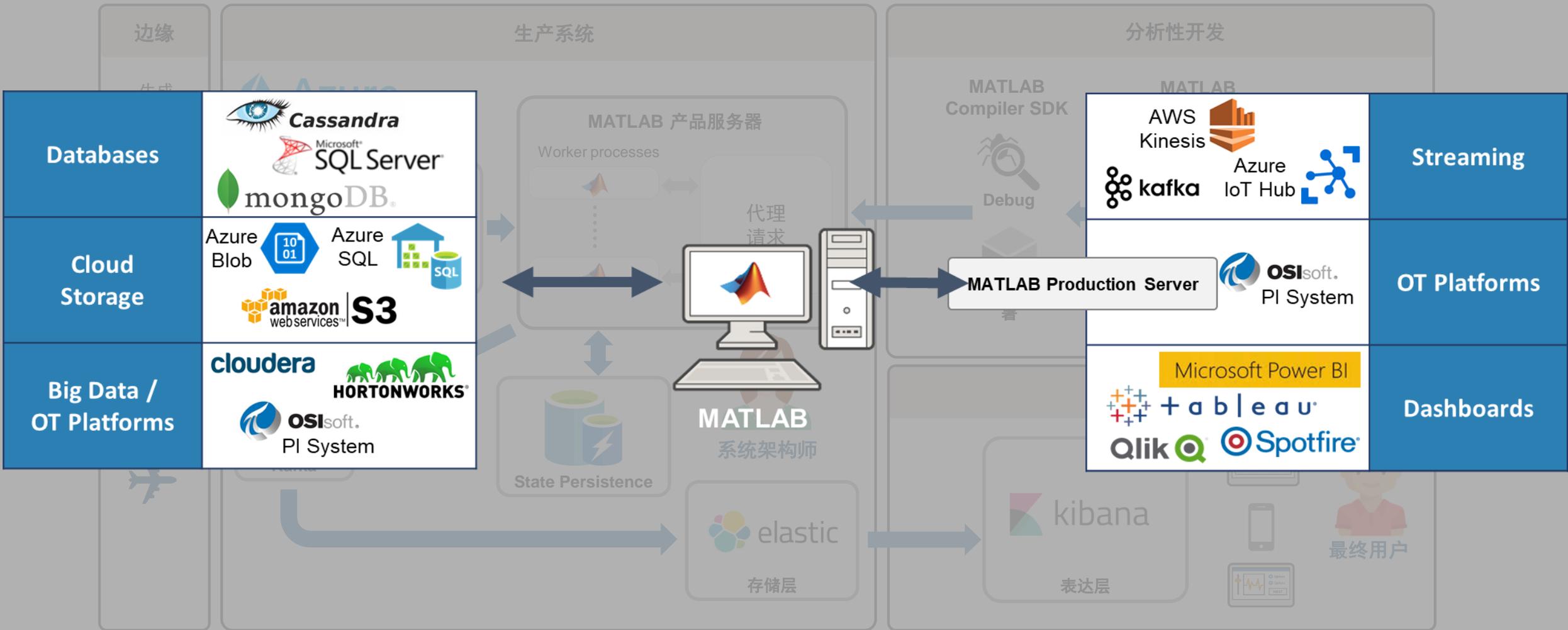


Fleet & Inventory Analysis

Azure 上的预测性维护架构

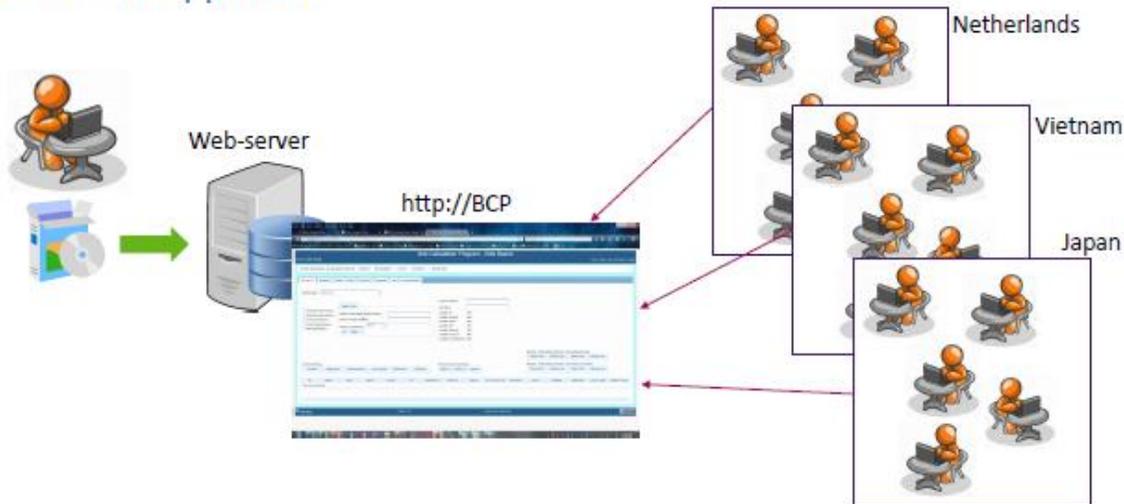


Azure 上的预测性维护架构



博世和SNCF已经成功实施了的生产系统

Web-based Approach



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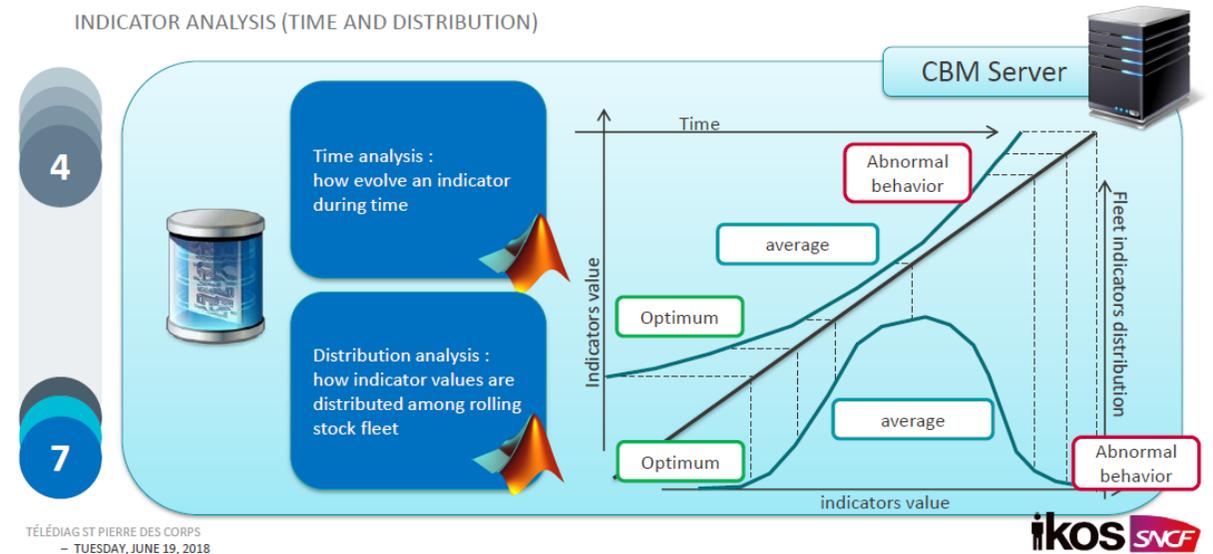


[Link to user story](#)

“仅需在1个地方更新软件...主要更新最多只需要1小时停机时间.....”

CBM – PROGNOSTIC

INDICATOR ANALYSIS (TIME AND DISTRIBUTION)

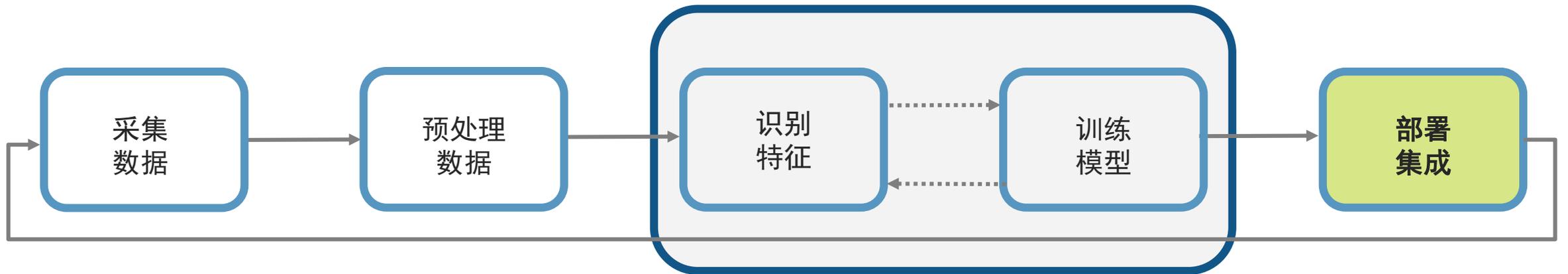


[Link to user story](#)

“..... [我们的解决方案]在不破坏现有流程的情况下优化整个维护流程.....”

MATLAB & Simulink 开发预测性维护系统的优势

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- 探索式特征提取和预测性建模
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MathWorks 帮助你从现在开始快速起步

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- [文档](#)
- [教程和练习](#)
- [咨询服务](#)
- [系列技术讲座](#)

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CONTENTS

Predictive Maintenance Toolbox

Design and test condition monitoring and predictive maintenance algorithms

Predictive Maintenance Toolbox™ lets you label data and estimate the remaining useful life (RUL) of a machine. The toolbox provides functions and an interactive app for ranking features using data-based and model-based methods, such as bearings and gearboxes by extracting features using spectral, and time-series analysis. You can monitor time-series data using frequency and time-frequency methods. To estimate RUL, you can use survival, similarity, and trend-based models.

You can analyze and label sensor data imported from distributed file systems. You can also label simulated Simulink® models. The toolbox includes reference experiments for batteries, and other machines that can be reused for maintenance and condition monitoring algorithms.

Getting Started
Learn the basics of Predictive Maintenance Toolbox

Manage System Data
Import measured data, generate simulated data, organize data

Preprocess Data
Clean and transform data to prepare it for extracting features

Identify Condition Indicators
Explore data at the command line or in the app to identify features

Detect and Predict Faults
Train decision models for condition monitoring and fault detection

Deploy Predictive Maintenance Algorithms
Implement and deploy condition-monitoring and predictive maintenance algorithms

Documentation All More ▾ Search Help

CONTENTS

Detect and Diagnose Faults

Fault Diagnosis of Centrifugal Pumps Using Steady State Experiments

Use a model-based approach for detection and diagnosis of different types of faults in a pumping system.

[Open Live Script](#)

Fault Diagnosis of Centrifugal Pumps Using Residual Analysis

Use a model parity-equations-based approach for detection and diagnosis of faults in a pumping system.

[Open Live Script](#)

Multi-Class Fault Detection Using Simulated Data

Use a Simulink model to generate faulty and healthy data, and use the data to develop a multi-class classifier to detect different faults.

[Open Live Script](#)

Analyze and Select Features for Pump Diagnostics

Use the Diagnostic Feature Designer app to analyze and select features to diagnose faults in a triplex reciprocating pump.

[Open Live Script](#)

Friction Change Detection

Fault Detection Using an Extended Kalman Filter

Use an extended Kalman filter for online estimation of the friction of a simple DC motor. Significant changes in the estimated friction are detected.

[Open Script](#)

Power Spectrum

Fault Detection Using Data Based Models

Use a data-based modeling approach for fault detection.

[Open Script](#)

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