

MATLAB CONFERENCE 2017

Predictive Maintenance with MATLAB and Simulink

Daryl Ning
Applications Engineer
MathWorks Australia



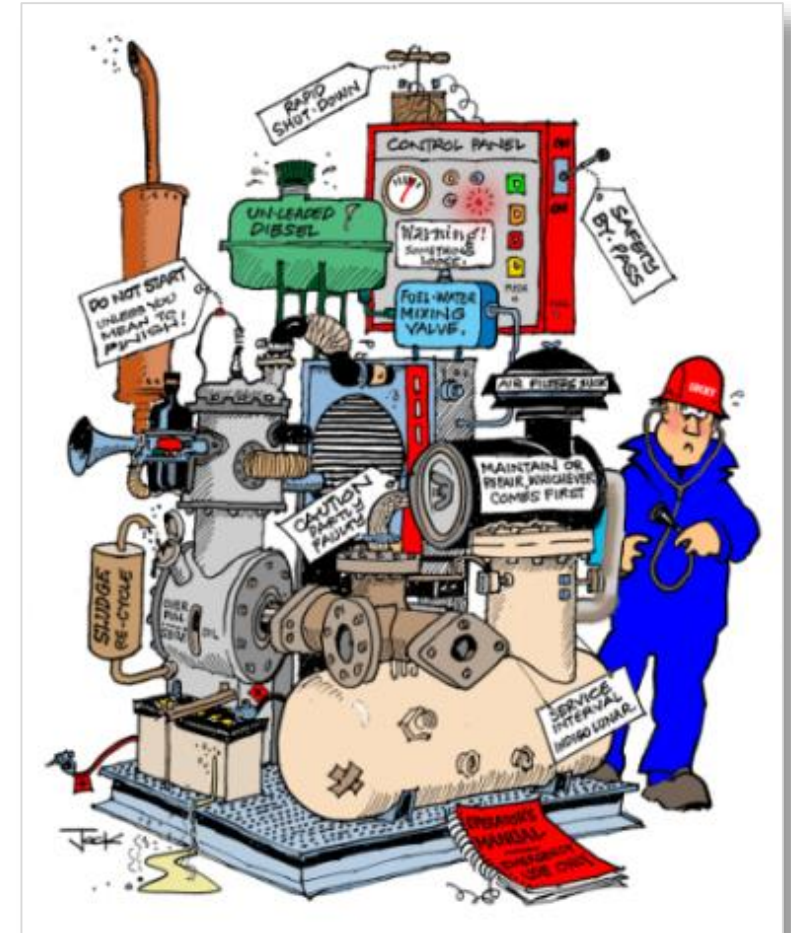
Predictive Maintenance

Identify and prevent failures before they occur:

- Reduces unnecessary maintenance
- Eliminates unplanned downtime

Consists of:

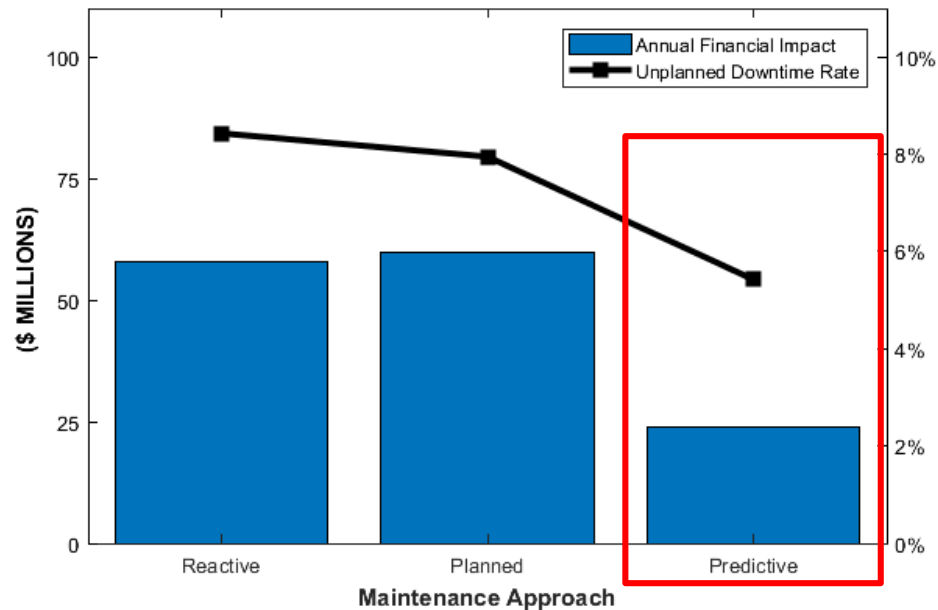
- Algorithms to predict Time-to-Failure or Remaining Useful Life
- Interfaces to communicate information to maintenance crew



Source: Tensor Systems

Why is Predictive Maintenance Important?

\$35M Saved
Unplanned downtime rate reduced by 30%



Source: GE Oil & Gas

- Improved Operating Efficiency
- New Revenue Streams
- Competitive Differentiator

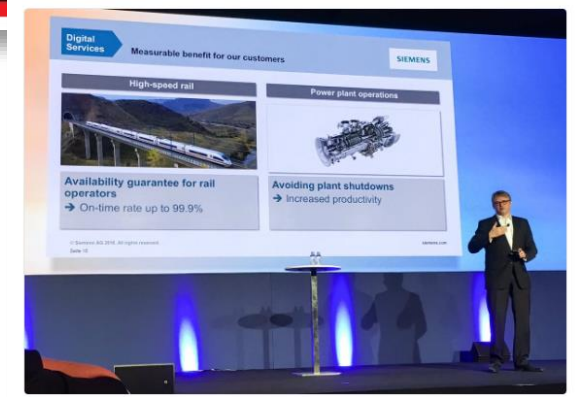
Industry Agrees that Predictive Maintenance is Important

- Improved operating efficiency

Bill Ruh Retweeted
GE Digital @GE_Digital · Feb 1
 What does the future of the #IIoT look like? Our CEO @BillRuh_GE explains in this new interview: stratbz.to/gASk308yoP0



Siemens @Siemens
 Thanks to predictive maintenance the #Velaro E trains between Barcelona and Madrid run w/ 99.9% availability #GartnerSYM




Measurable benefit for our customers

High-speed rail	Power plant operations
Availability guarantee for rail operators → On-time rate up to 99.9%	Avoiding plant shutdowns → Increased productivity

- New revenue streams

ABB Global @ABBgroupnews
 A game changer that opens the door to predictive maintenance ow.ly/4nc2TT #IIoT #HM16




SAP IoT @SAP_IoT
 John Deere uses machine alerts using #telematics for predictive maintenance and to lower downtime of assets v3.co.uk/v3-uk/news/234 ... #IIoT



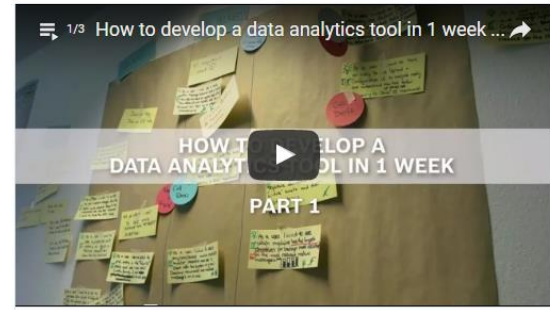
John Deere: Technology vendors need to feed agriculture's big data needs
 Farmers are hungry for IT solutions
v3.co.uk

- Competitive differentiator

Intel IoT @IntelIoT
 #DYK predictive maintenance can cut yield losses by 25%? Major benefits of #IIoT: intel.ly/2dg7Otm



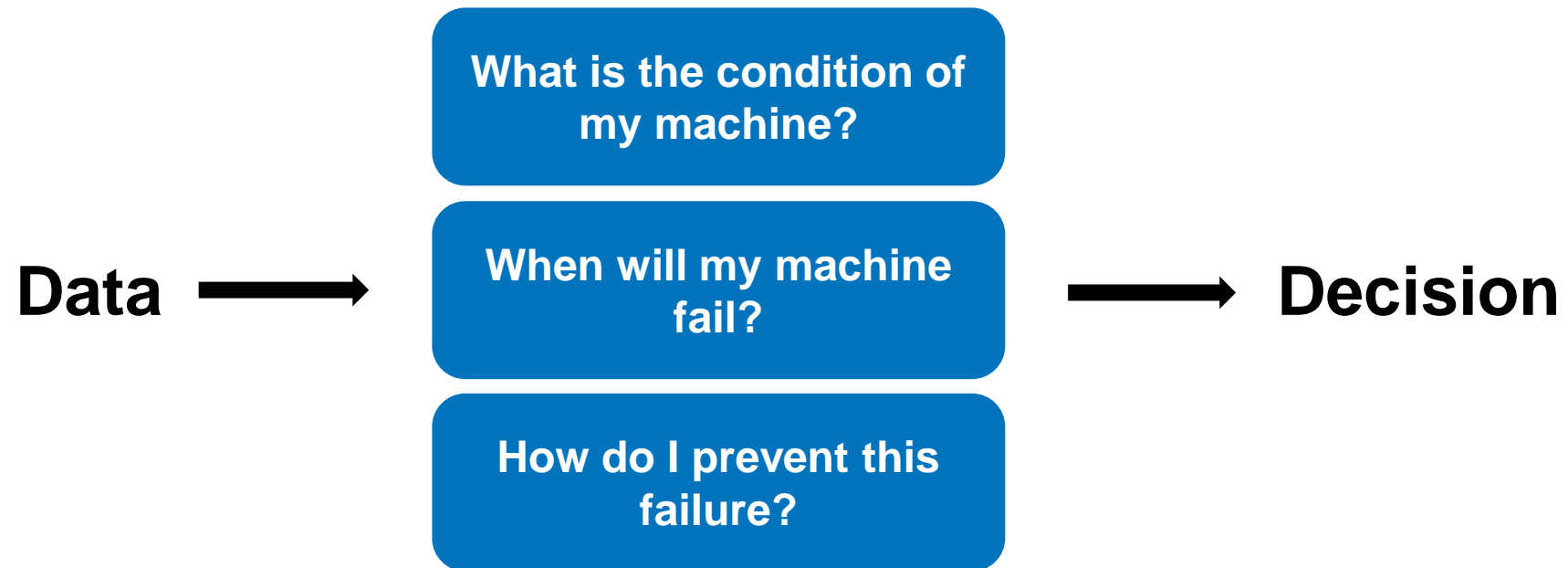
Software Innovations @BoschSI · Jan 31
 How to develop a #DataAnalytics tool for #PredictiveMaintenance in 1 week? youtube.com/watch?v=9mas0b... #IIoT #Industry40



How to develop a data analytics tool in 1 week (Part 1)
 A team of data scientists, manufacturing & software experts at Bosch Software Innovations developed a data analytics tool for predictive maint...
youtube.com

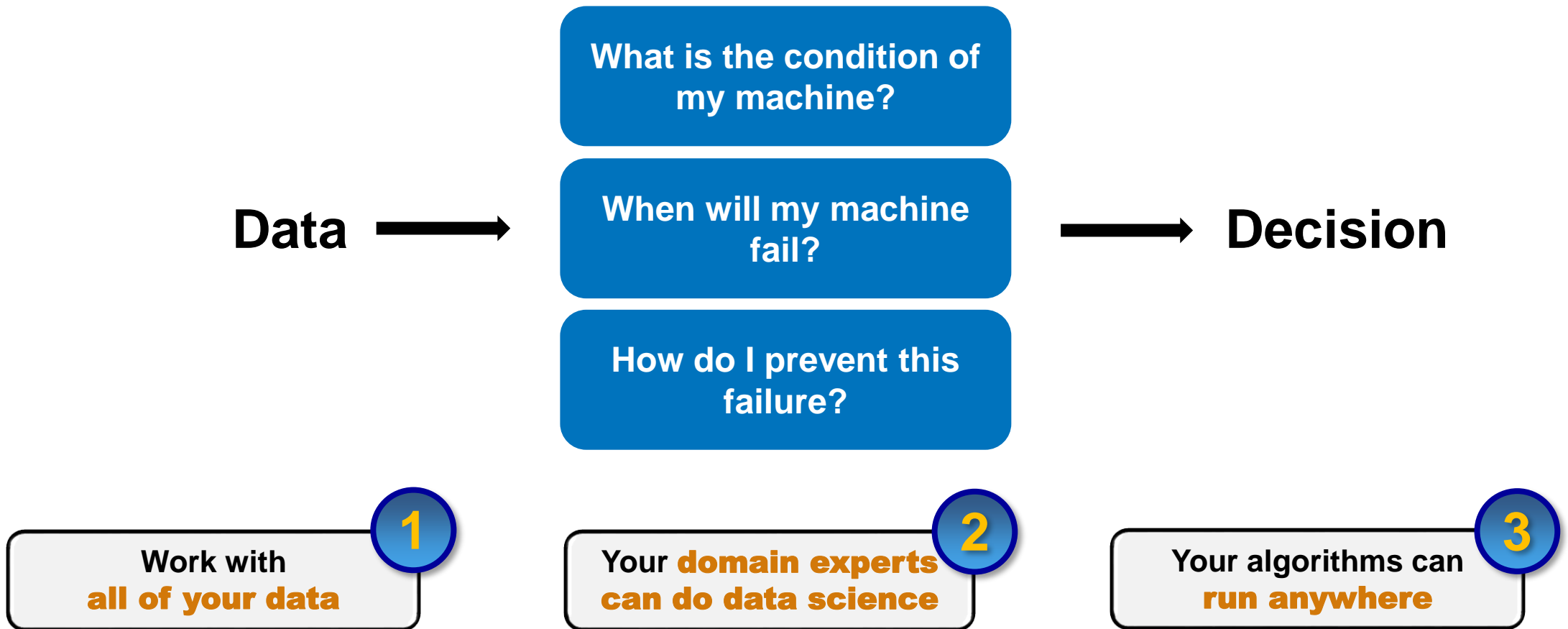
What should a Predictive Maintenance Algorithm do?

Turn large volumes of complex data into decisions



MATLAB Helps Build Predictive Maintenance Algorithms

Turn large volumes of complex data into decisions



Baker Hughes Develops Predictive Maintenance Software for Gas and Oil Extraction Equipment

Challenge

Develop a predictive maintenance system to reduce pump equipment costs and downtime

Solution

Use MATLAB to analyze nearly one terabyte of data and create a neural network that can predict machine failures before they occur

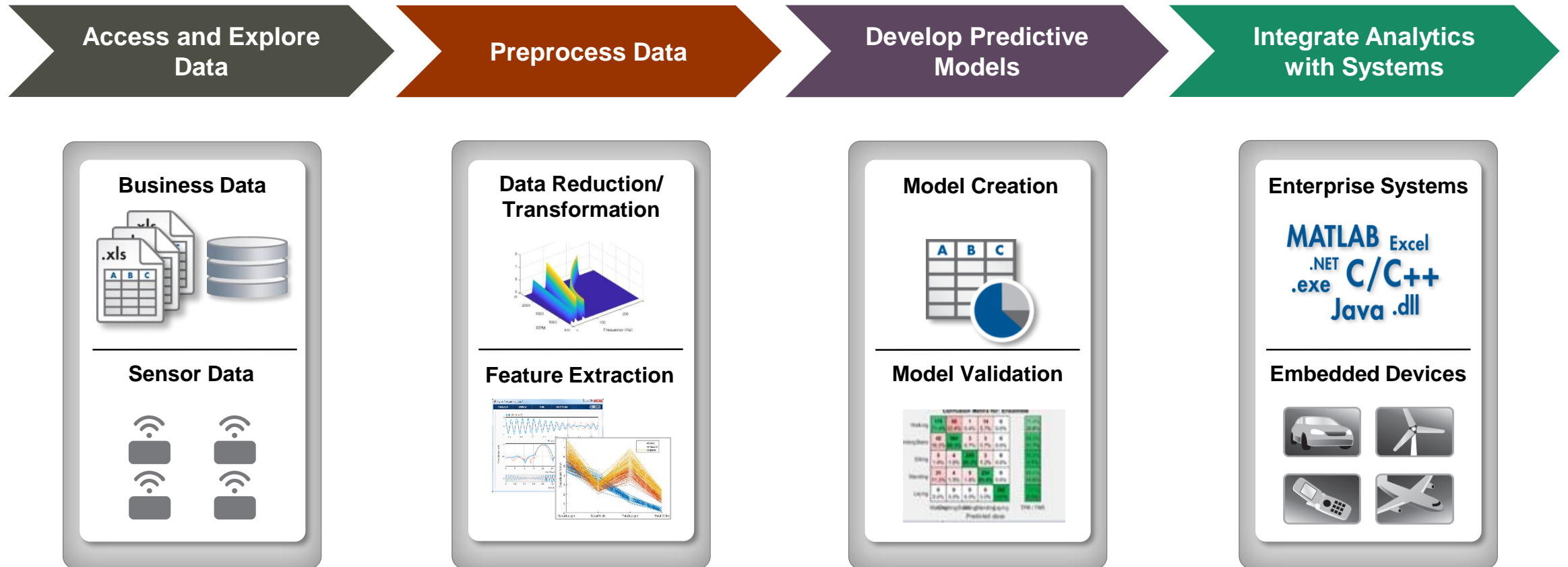
Results

- **Savings of more than \$10 million projected**
- **Development time reduced tenfold**
- **Multiple types of data easily accessed**



Truck with positive displacement pump.

Predictive Maintenance Algorithm Workflow



Access and Preprocess Data



Business Data

Sensor Data

1

**Data Reduction/
Transformation**

Feature Extraction

Model Creation

Model Validation

Enterprise Systems

MATLAB Excel
.NET C/C++
.exe Java .dll

Embedded Devices

Access and Preprocess Data

Access and Explore Data

Business Data



Sensor Data

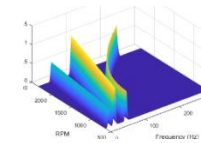


Challenges

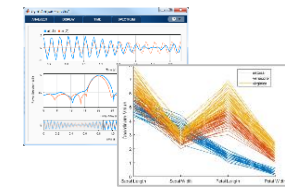
- I don't have enough data
- I have no data
- I have too much data to handle easily
- I have too many data sources
- My data is too messy

Preprocess Data

Data Reduction/ Transformation



Feature Extraction



Access and Preprocess Data

Access and Explore Data

Challenges

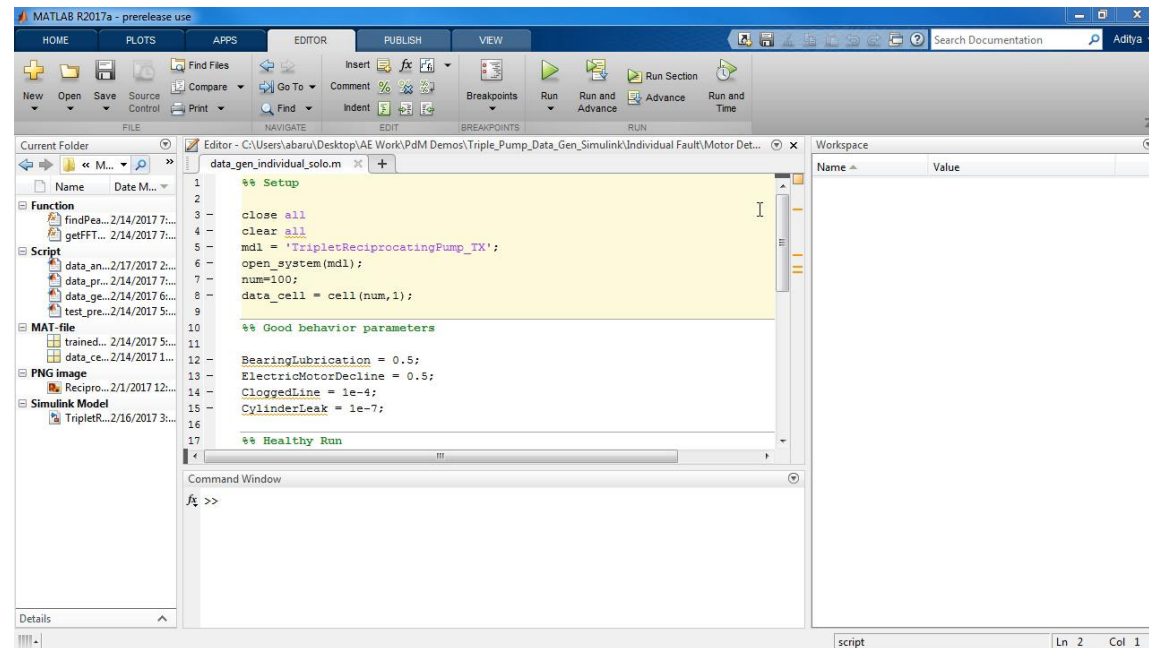
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Preprocess Data

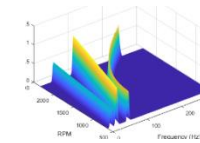
Business Data



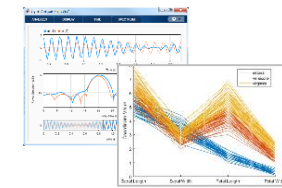
Sensor Data



Data Reduction/ Transformation



Feature Extraction



Access and Preprocess Data

Access and Explore Data

Challenges

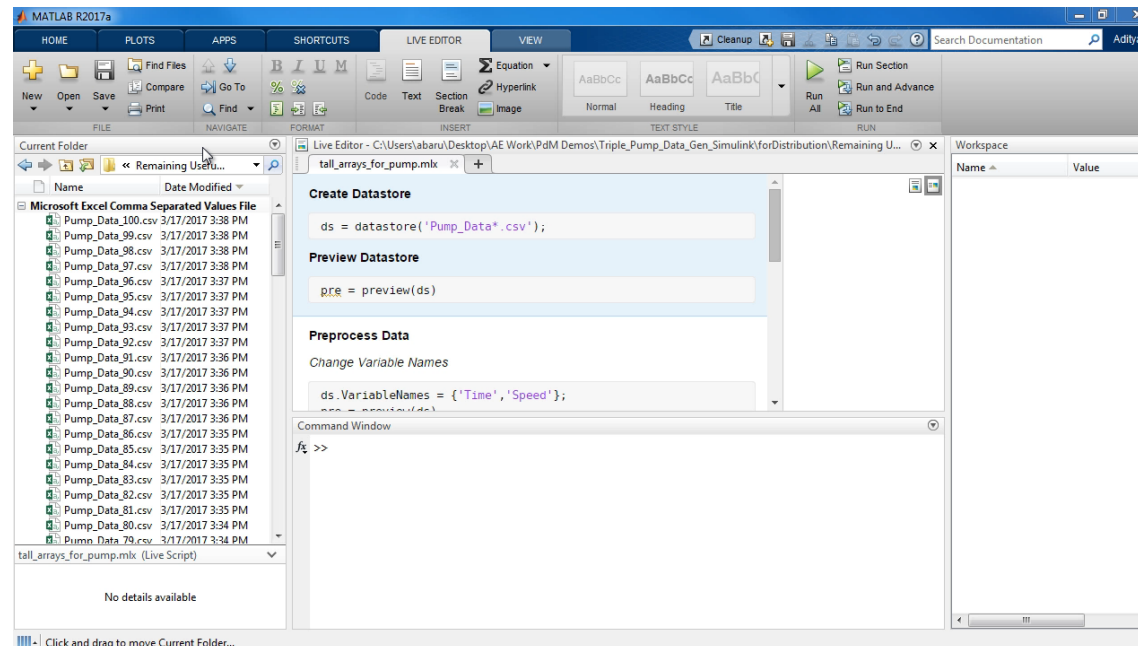
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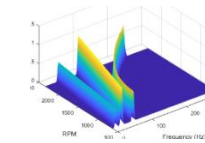
Business Data



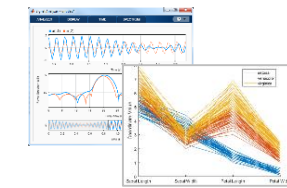
Sensor Data



Data Reduction/ Transformation



Feature Extraction



Access and Preprocess Data

1
Work with **all of your data**

Access and Explore Data

Preprocess Data

Business Data

Sensor Data

Databases

Images

HDFS

Files

Signals

Videos

- Point and click tools to access variety of data sources
- High-performance environment for big data
- Built-in algorithms for data preprocessing

Data Reduction/Transformation

Feature Extraction

Access and Preprocess Data

- Baker Hughes Develops Predictive Maintenance Software for Gas and Oil Extraction Equipment

“MATLAB gave us the ability to convert previously unreadable data into a usable format; automate filtering, spectral analysis, and transform steps for multiple trucks and regions; and ultimately, apply machine learning techniques in real time to predict the ideal time to perform maintenance.”

– Gulshan Singh, Baker Hughes



Build Predictive Models



Business Data

Sensor Data

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**Data Reduction/
Transformation**

Feature Extraction

2

Model Creation

Model Validation

Enterprise Systems

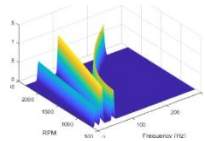
MATLAB Excel
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Embedded Devices

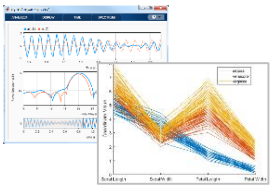
Build Predictive Models

Preprocess Data

**Data Reduction/
Transformation**



Feature Extraction




Challenges


- I need to incorporate my domain knowledge
- I need to extract and verify health indicators
- I lack machine learning experience
- I have deadlines to meet

Develop Predictive Models

Model Creation



Model Validation



	Actual 0	Actual 1	Actual 2	Actual 3	Actual 4
Predicted 0	100	0	0	0	0
Predicted 1	0	100	0	0	0
Predicted 2	0	0	100	0	0
Predicted 3	0	0	0	100	0
Predicted 4	0	0	0	0	100

Build Predictive Models

Preprocess Data

Develop Predictive Models

Data Reduction/Transformation

Feature Extraction

```

1  Script_2_data_analyze_individual_solo.m
2  %% Setup
3  clear;
4  clc;
5  load('data_cell_14-Feb-2017_12_53_49.mat');
6
7  data_cell = flipud(data_cell);
8  c_1 = [0 0.4470 0.7410];
9  num=100;
10 data_freq_f = cell(100,1);
11
12 %% Get Healthy Run Data
13
14 tout = data_healthy(:,1);
15 yout = data_healthy(:,2);
    
```

Model Creation

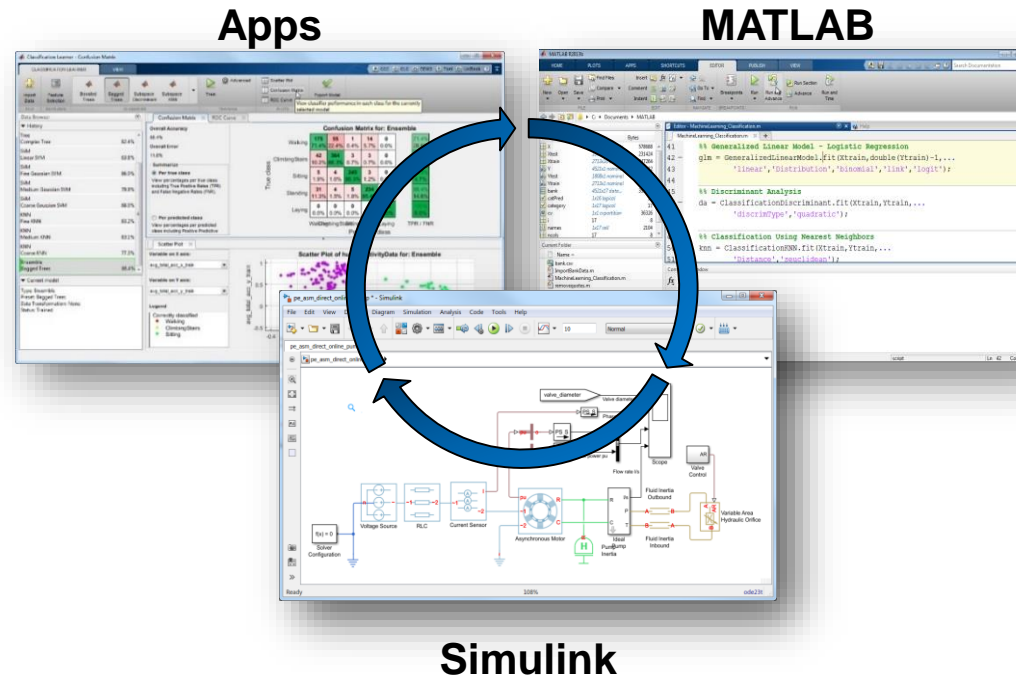
Model Validation

	Healthy	Warning	Alert	Failure	Unhealthy
Healthy	95%	4%	1%	0%	0%
Warning	10%	85%	3%	0%	0%
Alert	0%	10%	80%	10%	0%
Failure	0%	0%	0%	90%	10%
Unhealthy	0%	0%	0%	0%	100%

Build Predictive Models

2

Your domain experts can do data science



Data Reduction/Transformation

Feature Extraction

Model Creation

Model Validation

- Easy to use apps across multiple domains
- Documentation, examples, and videos to get started
- Automatic MATLAB code generation

Build Predictive Models

“As a manufacturing company we don’t have data scientists with machine learning expertise, but MathWorks provided the tools and technical knowhow that **enabled us to develop a production preventative maintenance system in a matter of months,**”

– Dr. Michael Kohlert, MONDI

“...[We] enable engineers to quickly and easily layout algorithms without special knowledge in computer science...”

– Jérôme Lacaille, Safran



SAFRAN
Snecma



Deploy and Integrate



Business Data

Sensor Data

1

**Data Reduction/
Transformation**

Feature Extraction

2

Model Creation

Model Validation

3

Enterprise Systems

MATLAB Excel
.NET C/C++
.exe Java .dll

Embedded Devices

Deploy and Integrate

Develop Predictive Models

Model Creation



Model Validation



Challenges

- I have multiple end users – plant managers, operations analysts, maintenance staff, etc.
- I have to allow access through different target platforms
- I need to scale to meet production needs
- I need to reduce bandwidth consumption

Integrate Analytics with Systems

Enterprise Systems

MATLAB Excel
 .NET C/C++
 .exe Java .dll

Embedded Devices



Deploy and Integrate

Develop Predictive Models

Integrate Analytics with Systems

Model Creation



Model Validation



Predictive Data Analytics

Home Demand Forecasting Web Service Description Documentation

Predictive Data Analytics
This website tightly integrates MATLAB analytics with web technologies for demonstrating predictive data analytics models in production with live data.

[Get started »](#)

Demand Forecasting

Forecast electricity demand for US power grids with live data from ISOs and weather stations using Neural Network models. Forecasts can be compared to past data as well as normal weather. Prediction bands at different confidence intervals also quantify uncertainty in forecast.

[Start »](#)

Web Service Information

Documentation on end points and query parameters for demand forecast web services

[Read more](#)

App Documentation

Documentation of the entire web application and its components

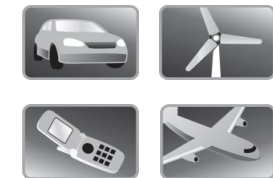
Coming soon!

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Enterprise Systems

MATLAB Excel
.NET C/C++
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Embedded Devices




Deploy and Integrate

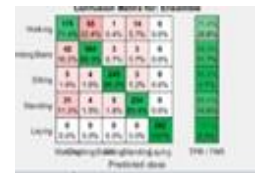
3
 Your algorithms can **run anywhere**

Develop Predictive Models

Model Creation

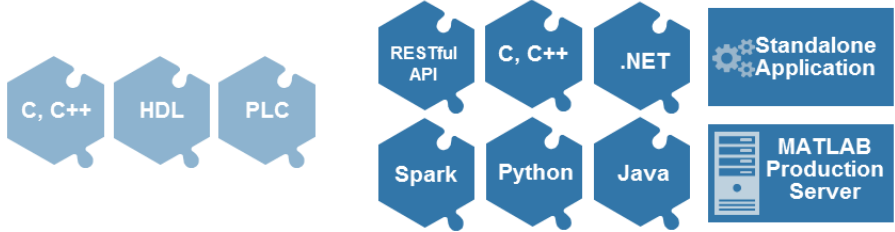


Model Validation



MATLAB + SIMULINK

Code Generation
Compiled Applications



Embedded Hardware Enterprise Systems





- Royalty-free deployment
- Web services, apps, and cloud platforms
- Computation on smarter edge devices
- Automatic C/C++ code generation

Integrate Analytics with Systems

Enterprise Systems

MATLAB Excel
 .NET .exe C/C++
 Java .dll

Embedded Devices

Deploy and Integrate

*“The protection algorithms for our conventional HVDC system took about six months to develop and test in C. **I re-implemented the same algorithms in Simulink and Stateflow and had them working in a single week.**”*

– Anthony Totterdell, Alstom Grid

*“**Using MATLAB and MATLAB Compiler, I can develop an application at least 100 times faster than I could with Visual Basic or C.** The time we saved on the very first application that we wrote in MATLAB more than paid for the software.”*

– Roger Schultz, Halliburton Energy Services



Summary: MATLAB Helps Build Predictive Maintenance Algorithms



Business Data

Sensor Data

1

**Data Reduction/
Transformation**

Feature Extraction

2

Model Creation

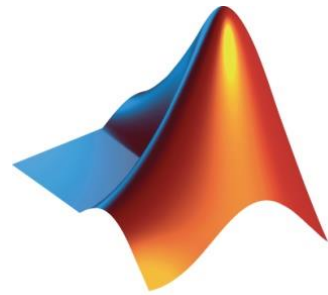
Model Validation

3

Enterprise Systems

MATLAB Excel
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Embedded Devices



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