

MATLAB EXPO 2017

Developing Analytics and Deploying IoT Systems

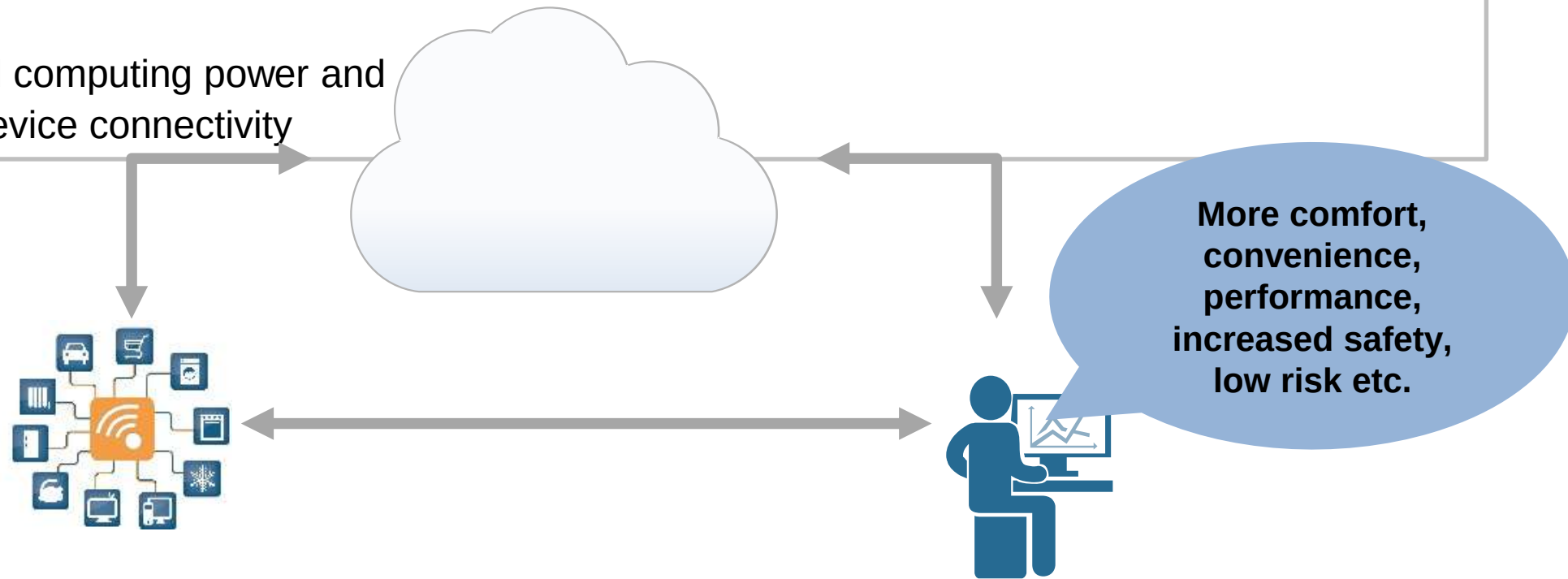
Amit Doshi

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What is Internet of things (IoT)?

- Internet of Things (IoT) is internetworking of a large number of **embedded devices (“things”)** which are **connected to the Internet**. These connected devices **communicate with people and other things** and often provide **sensor data to cloud storage and cloud computing resources** where the **data is processed and analyzed to gain important insights**.
- **Why now –**
 - Cheap cloud computing power and
 - Increased device connectivity



'Chips in everything' & the rise of 'Ubiquitous sensing'

Extracting insights from sensor data... a common practice

Deloitte.

Estimates of the size of the IoT market vary. For instance, Gartner expects it to include nearly 26 billion devices, with a "global economic value-add" of \$1.9 trillion by 2020.³

Human Applications:

- Medical
- Leisure
- Sports/Fitness
- Military
- Social
- Retail
- Security

HealthLeaders
Tip of the week: Incorporate ADL tracking tools in your everyday care planning

Science & Technology
Analytics: sensor customer behavior analysis

mobihealthnews
NIH's \$10.8M grant for sensor-enabled congestive heart failure, smoking cessation tools

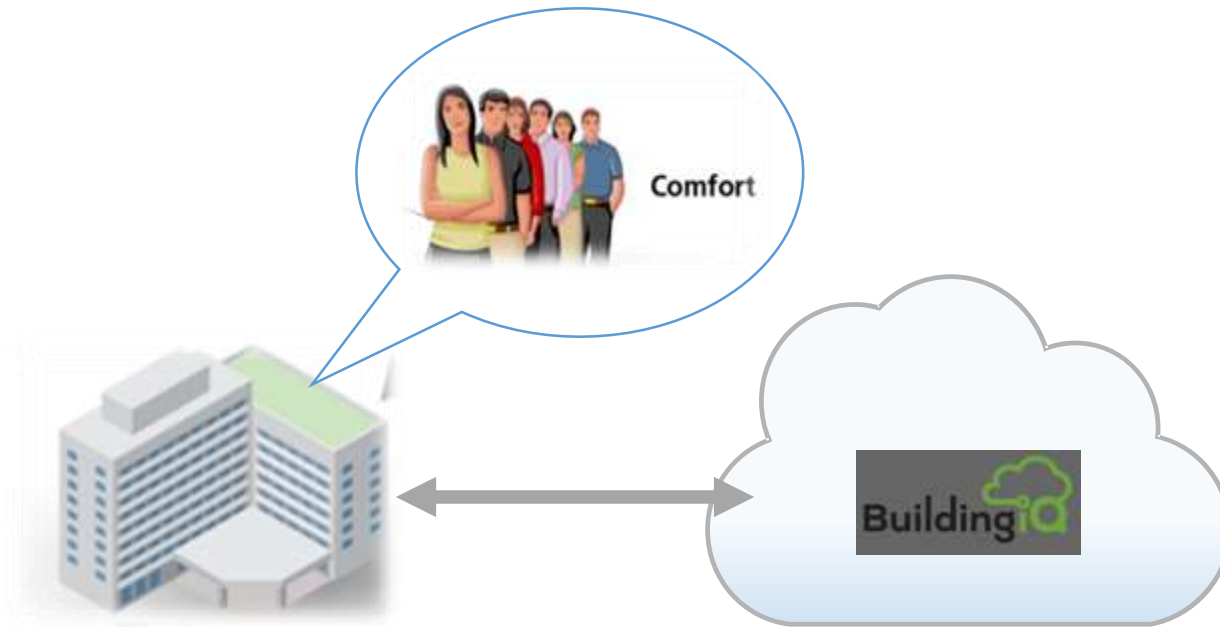


DEFENSE SYSTEMS
Army aims to speed up data fusion on the battlefield

By Kevin McCaney | Mar 02, 2015

Example – BuildingIQ

Cloud based adaptive building energy management

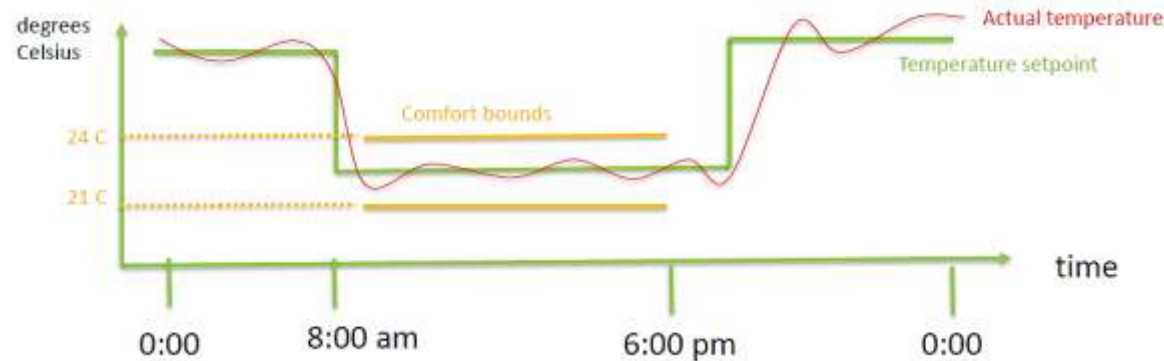


Challenge

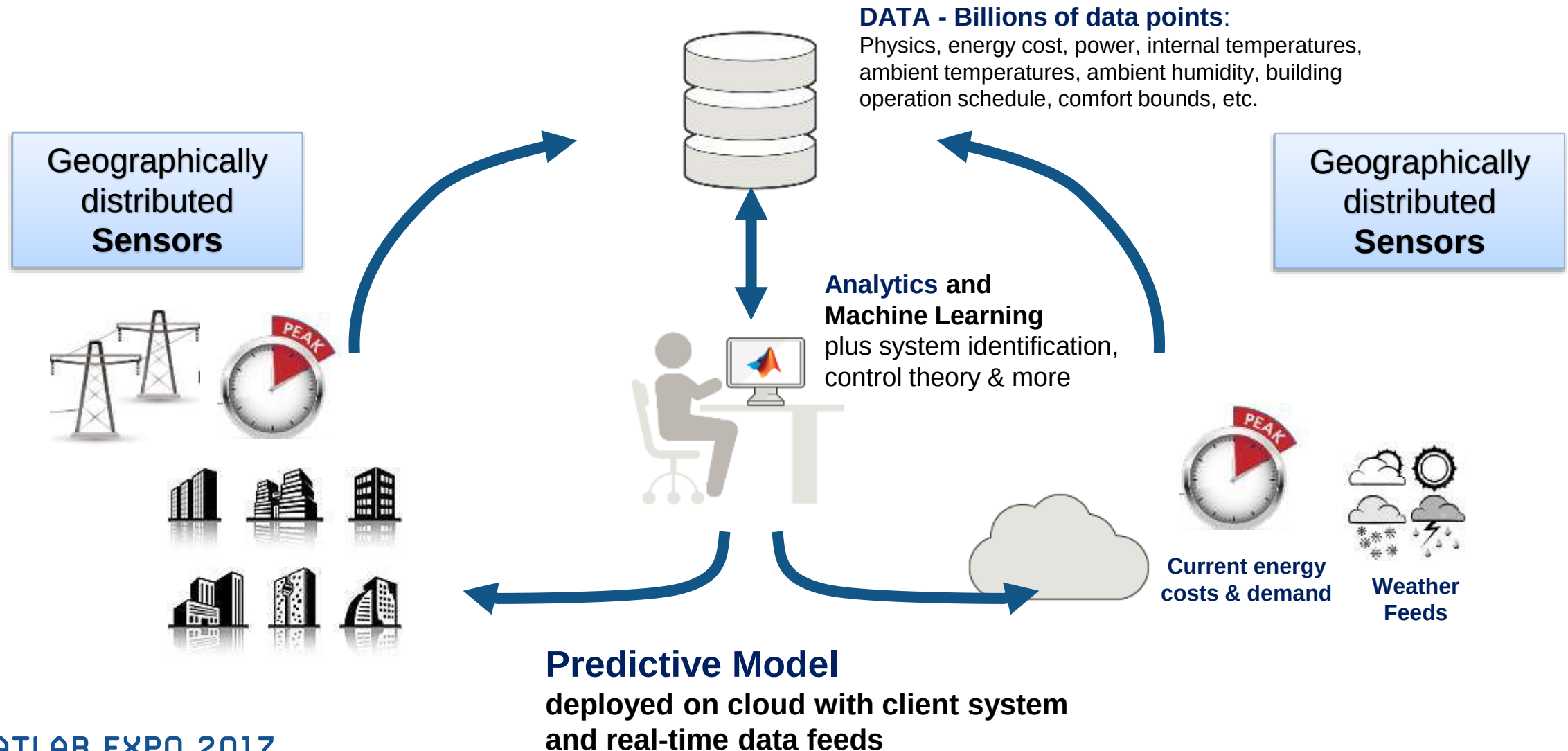
Minimize energy costs of large-scale commercial buildings without compromising tenants comfort.

Solution

Develop cloud based real-time adaptive system via proactive, predictive optimization algorithm.

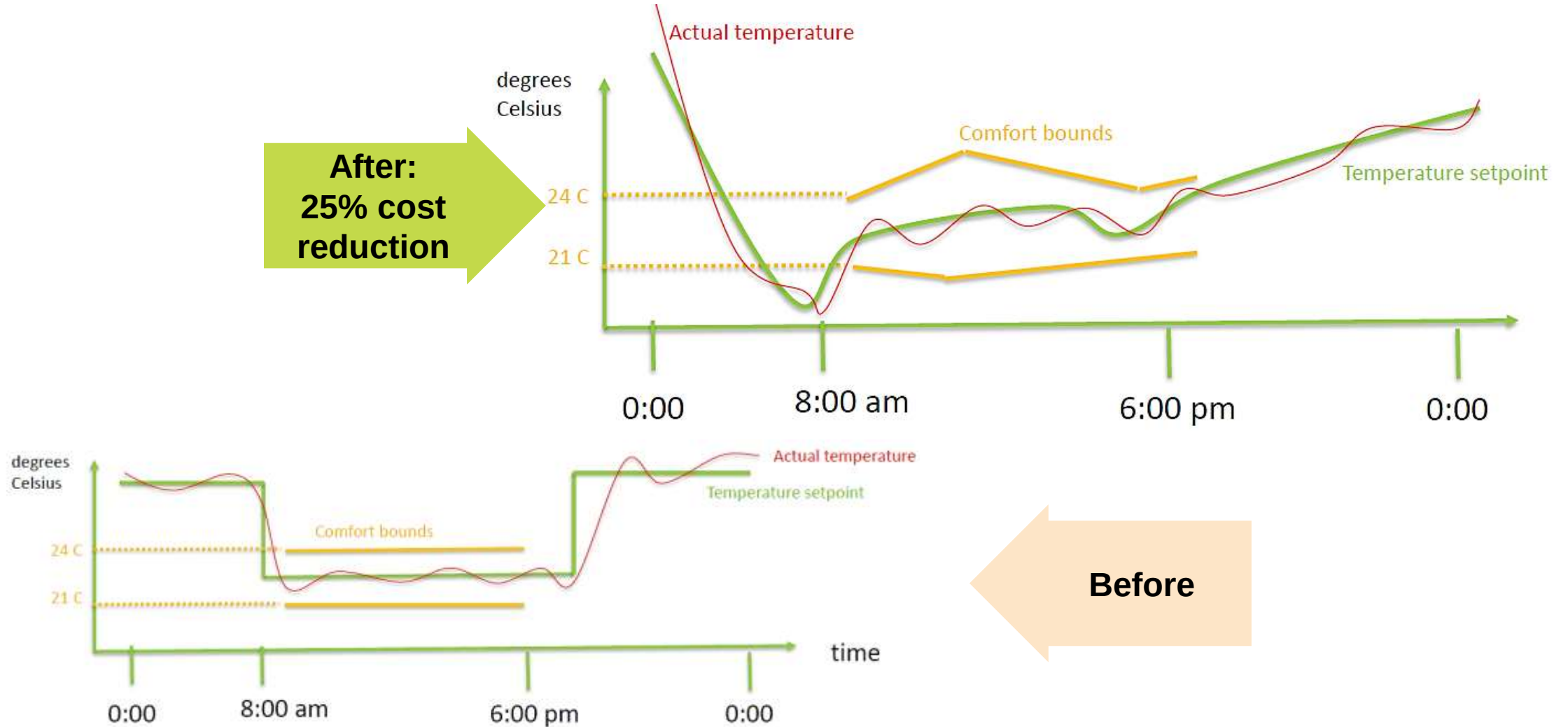


Real-time, closed-loop optimization algorithms

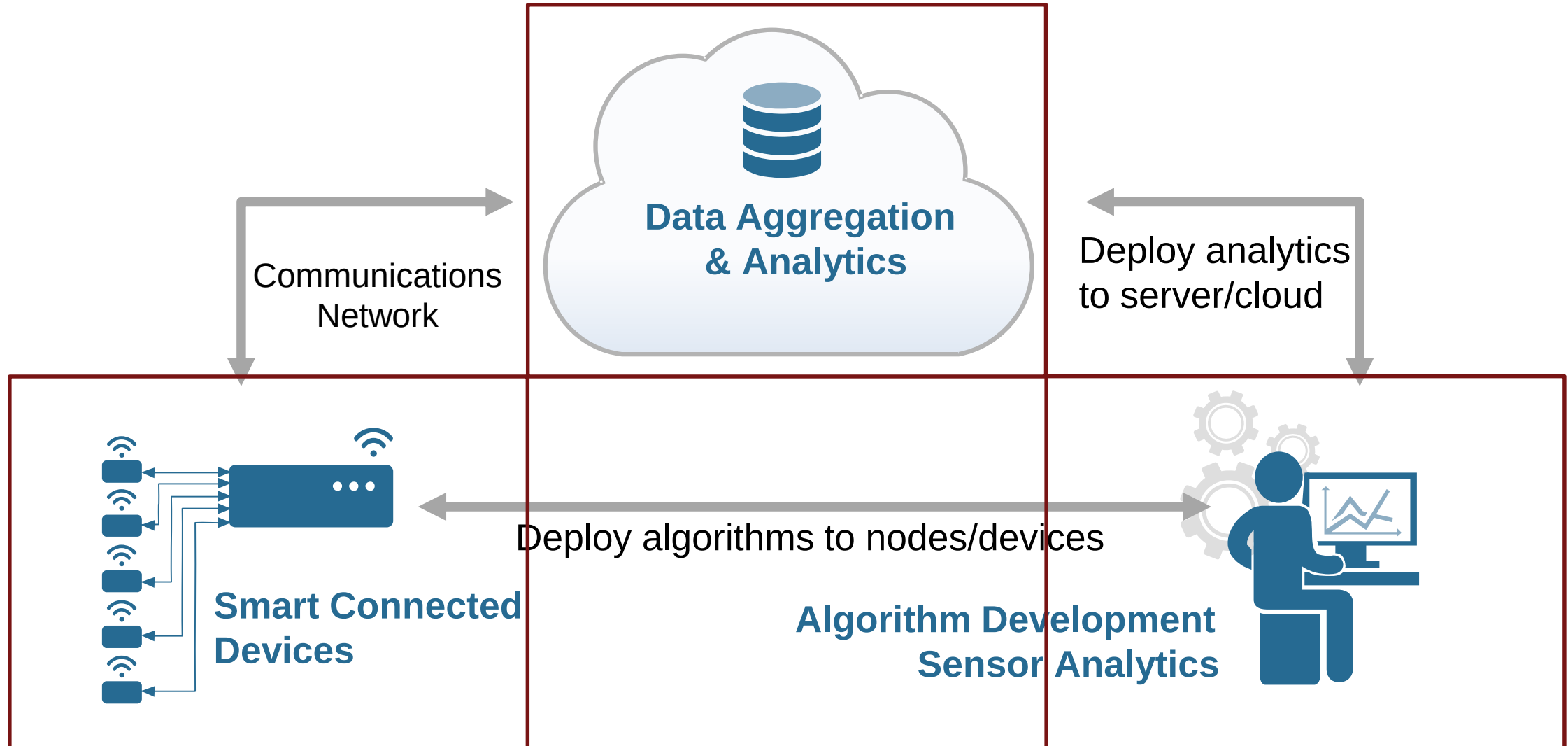


Example – BuildingIQ

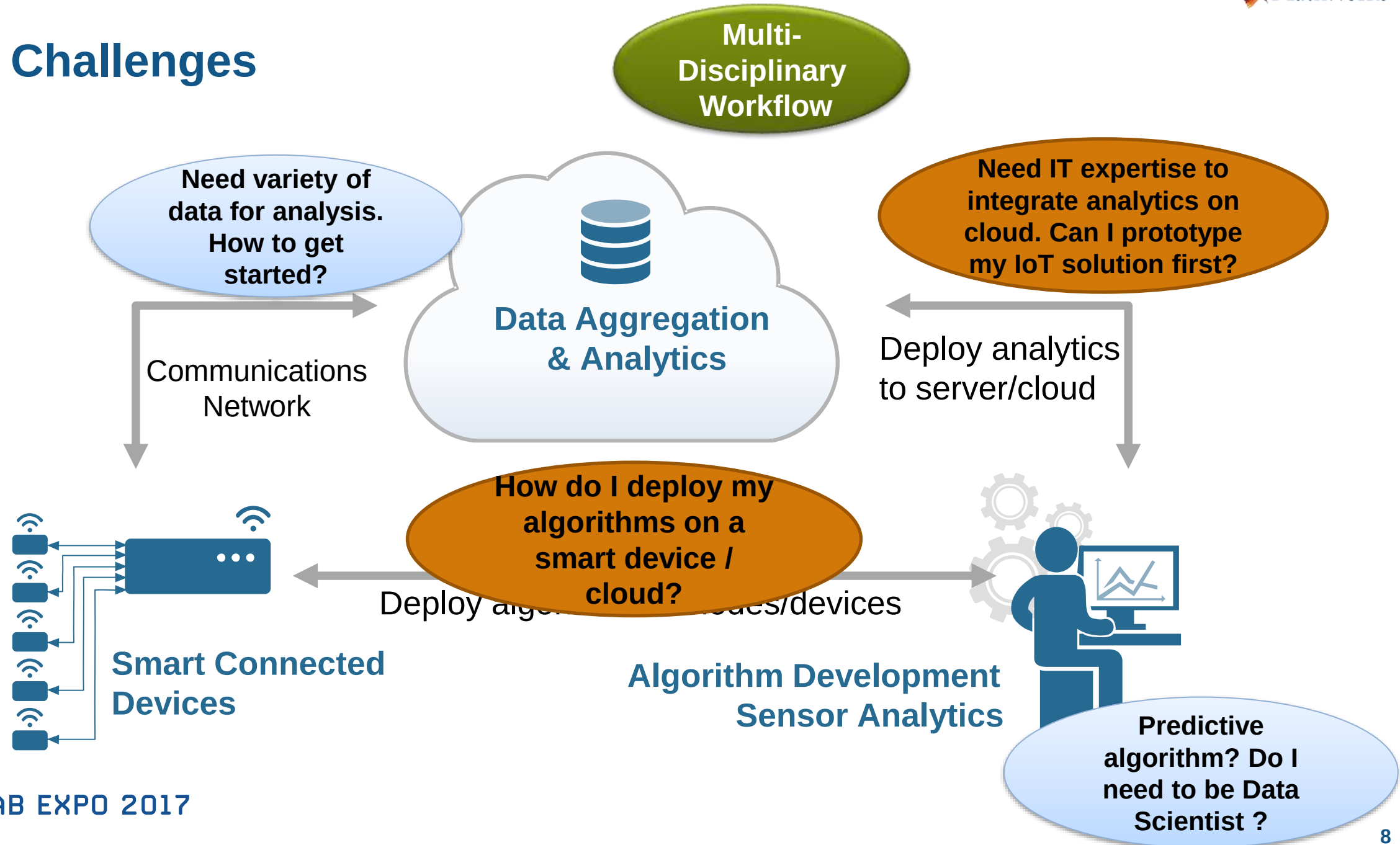
Cloud based adaptive building energy management



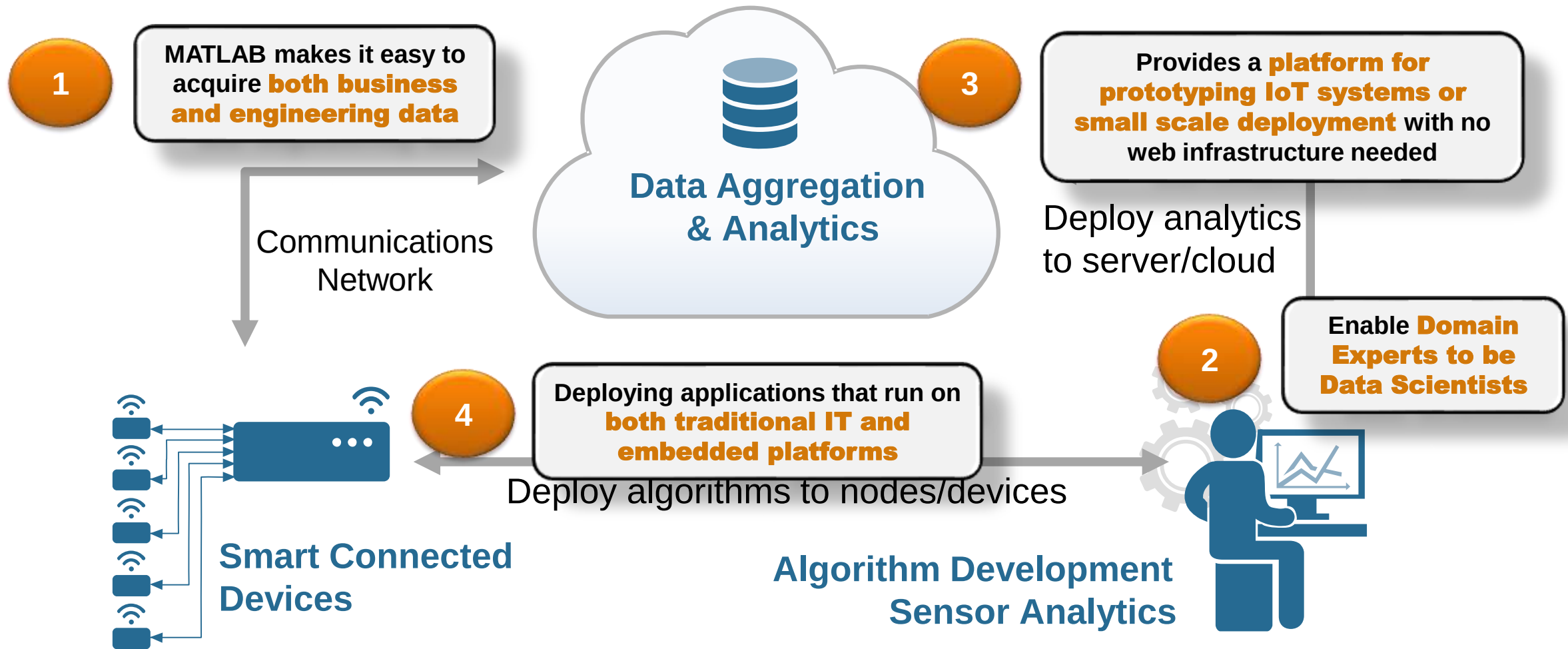
High Level Architectural View of Internet of Things



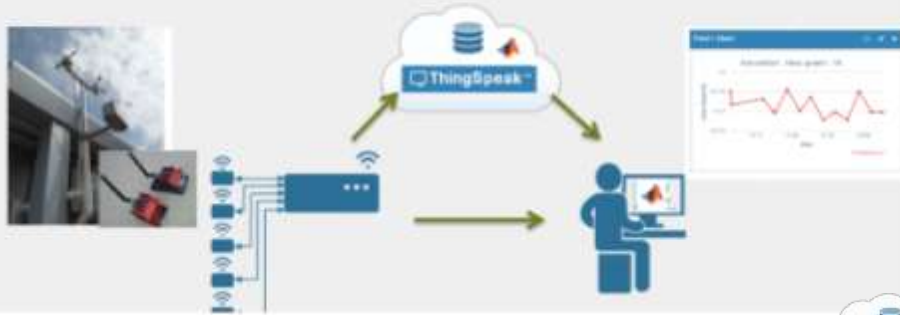
IoT Challenges



How MathWorks Addresses IoT Challenges?



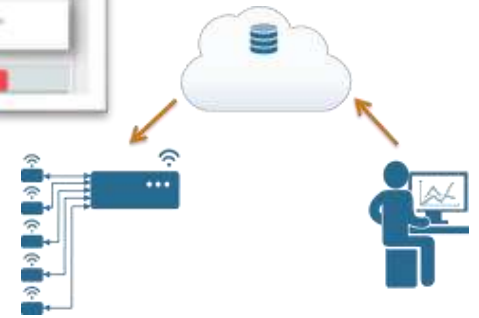
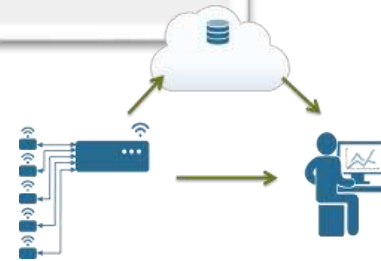
Example 1: Weather monitoring using ThingSpeak and MATLAB



Example 2: Low Tide Prediction Using MATLAB And ThingSpeak

Challenge
Boats get stuck in mud at low tide

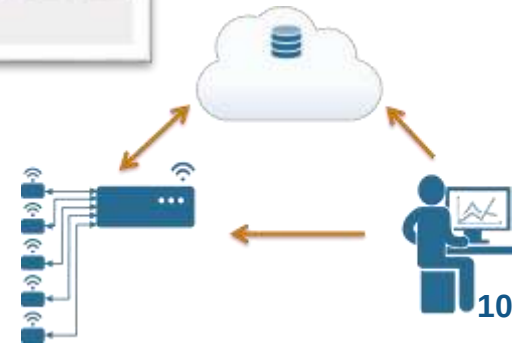
Solution
Advance notification of low tide



Example 3: Human Activity Analysis and Classification

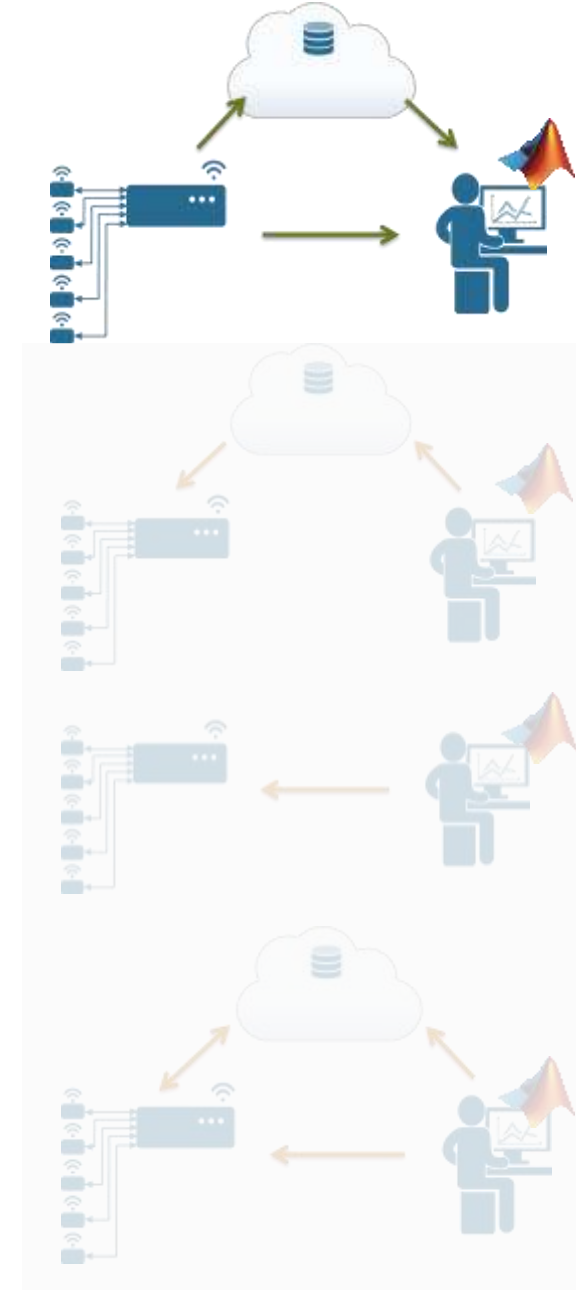


Example 4: Traffic monitoring can be used for smart traffic light management



Examples for Today

- Data acquisition from edge nodes and analysis using MATLAB
 - Measure, explore, discover weather patterns
- Develop analytics using MATLAB and deploy as a web service
 - Forecast wind driven tide levels
- Develop analytics using MATLAB and deploy on a smart device
 - Human Activity Analysis and Classification
- Develop analytics using MATLAB and optimal partition it on an edge device and cloud
 - Smart traffic monitoring using Raspberry Pi webcam



Get Started with IoT by Accessing Sensor Data in MATLAB



■ Analog Input



```
[data, time]
= StartForeground(s);
```

• Serial Port



```
s1 = serial('COM1');
l = i2c('aardvark', 0,...
Hex2dec('50')
A = fread (obj);
```

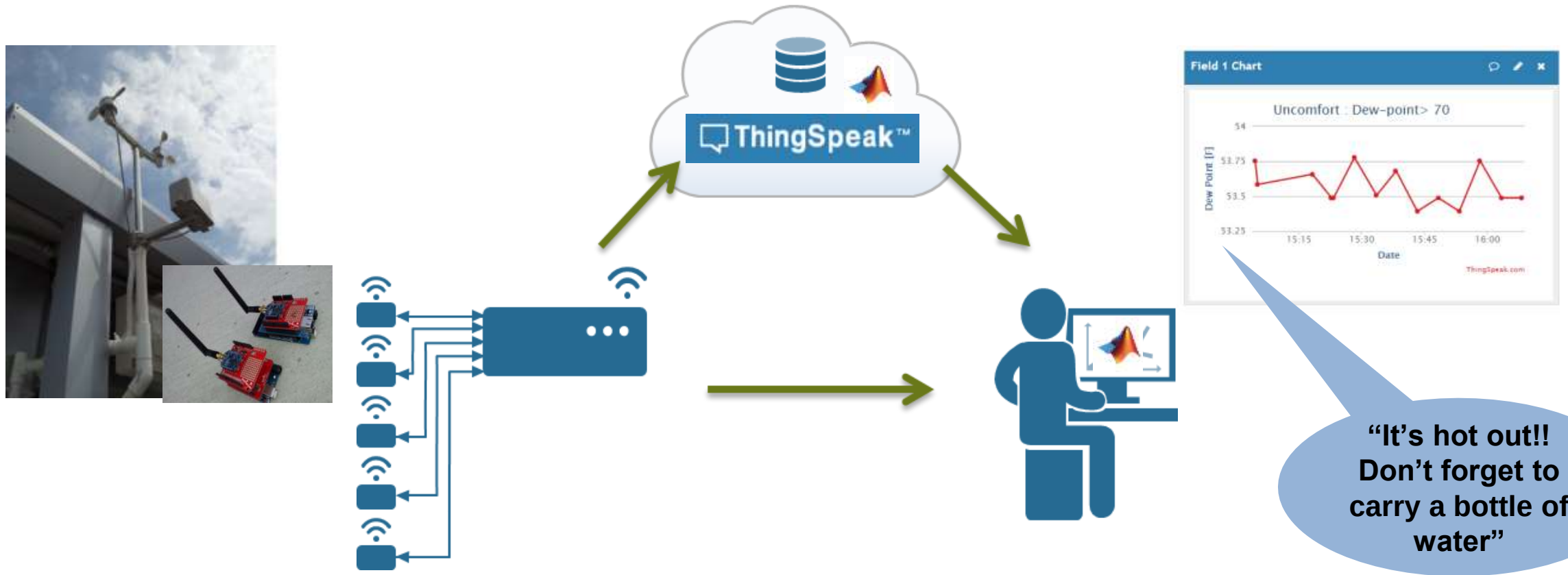
• TCP/IP

• UDP



```
t = tcpip ('localhost', 30000,
'NetworkRole', 'server');
fread (t, 10)
```

Example 1: Weather monitoring using ThingSpeak and MATLAB



What Is ThingSpeak?

Web Site For People

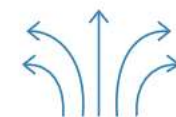
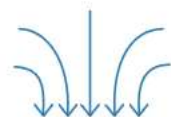


Web Service for Devices

```
{
  - channel: {
    id: 38629,
    name: "Car Counter",
    description: "Counting number of cars passing a reference line in 15 sec interval",
    latitude: "42.28",
    longitude: "-71.35",
    field1: "Number of Westbound Cars",
    field2: "Number of Eastbound Cars",
    created_at: "2015-05-19T20:14:03Z",
    updated_at: "2016-05-19T10:36:35Z",
    last_entry_id: 1477231
  },
  - feeds: [
    - {
      created_at: "2016-05-19T10:36:20Z",
      entry_id: 1477230,
      field1: "18.000000",
      field2: "8.000000"
    },
    - {
      created_at: "2016-05-19T10:36:35Z",
      entry_id: 1477231,
      field1: "18.000000",
      field2: "14.000000"
    }
  ]
}
```


ThingSpeak

- New MathWorks web service hosted on AWS
- Lets you collect, analyze and act on data from “things” such as Arduino[®], Raspberry Pi[™], BeagleBone Black, and other hardware
- Over **130,000** users worldwide
- It has **MATLAB** for IoT Analytics



Example 1: Weather monitoring using ThingSpeak and MATLAB

The screenshot displays the MATLAB R2017a environment. The top window shows the MATLAB Editor with a script titled 'weatherDataDownloadAndAnalysis.m'. The script includes comments explaining the purpose of the code and the formula for calculating the dew point. The Command Window at the bottom displays a table of weather data.

Script Content:

```

39
40 %% Calculate Dew Point
41 % Now we are ready to answer our second question about how temperature and
42 % dew point have varied over the past week. The dew point is the
43 % temperature at which the air (when cooled) would become saturated with
44 % water vapor. The more humid the air mass, the higher the dew point. Dew
45 % point is also sometimes a measure of discomfort. When the dew point is
46 % over 65 degrees, many people start to say the air feels "sticky." Dew
47 % points over 70 feel uncomfortable to many. A common estimation for dew
48 % point, tdp, can be found using the equations and constants (see
49 % <http://en.wikipedia.org/wiki/Dew_point Reference>) shown below:
50 % $stdp = \frac{c}{\gamma} \ln\left(\frac{b - \gamma}{b + \gamma}\right)$
51 %
52 % $\gamma = \ln(\text{humidity}/100) + \frac{c}{b + \text{tempC}}$

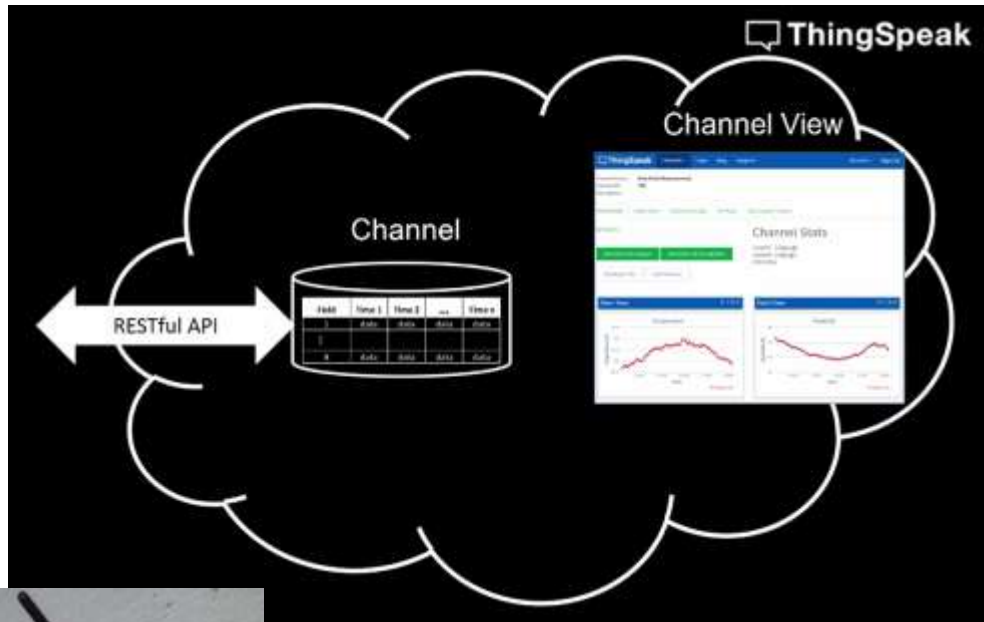
```

Command Window Output:

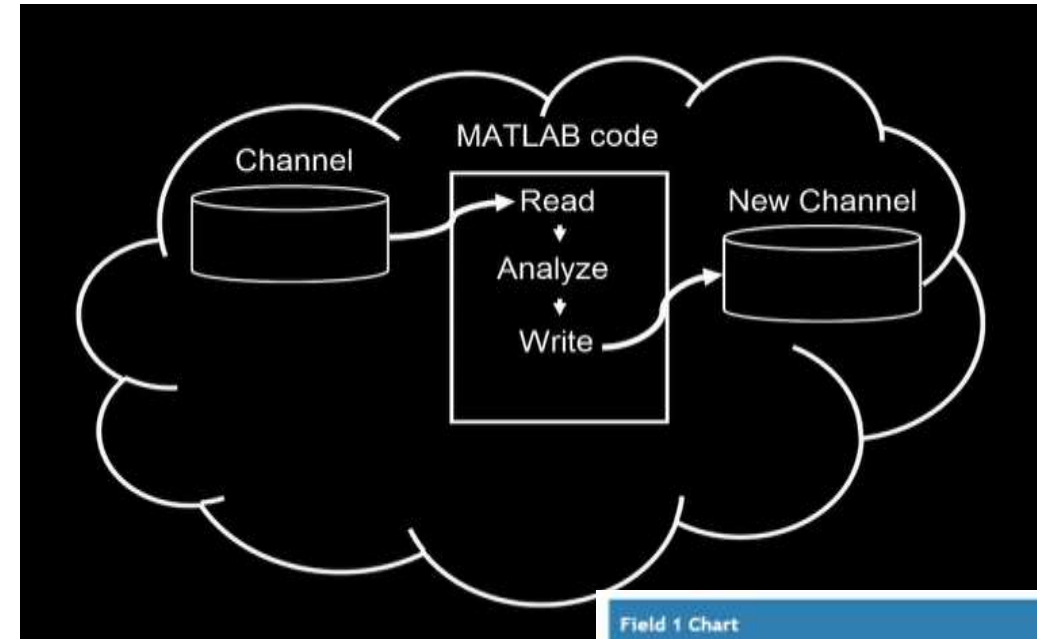
Parameter	Value	Date/Time
Wind Direction (North = 0 degrees)	360	'14-Apr-2017 14:30:53'
Wind Speed (mph)	21.6	'15-Apr-2017 15:31:24'
% Humidity	79	'16-Apr-2017 00:00:32'
Temperature (F)	91.3	'11-Apr-2017 14:33:24'
Rain (Inches/minute)	0	'10-Apr-2017 12:28:24'
Pressure ("Hg)	30.1	'13-Apr-2017 18:30:57'
Power Level (V)	4	'10-Apr-2017 12:28:24'
Light Intensity	66	'11-Apr-2017 15:02:07'

Example 1: Weather monitoring using ThingSpeak and MATLAB

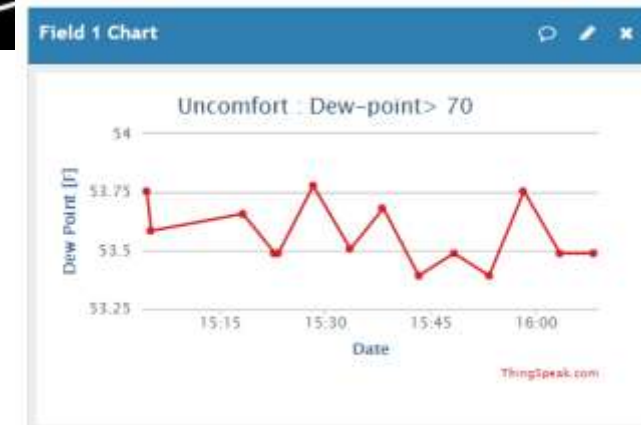
Data Aggregation



Data Analysis

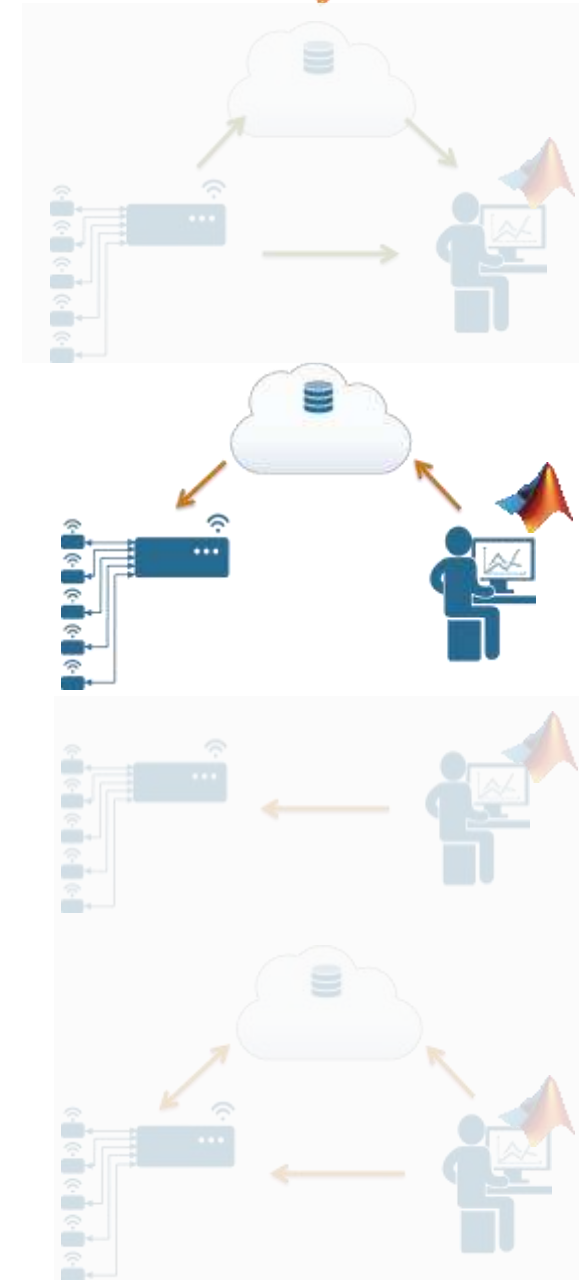


Editing algorithm on cloud is very easy as it's running MATLAB



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Example 2: Low Tide Prediction Using MATLAB And ThingSpeak

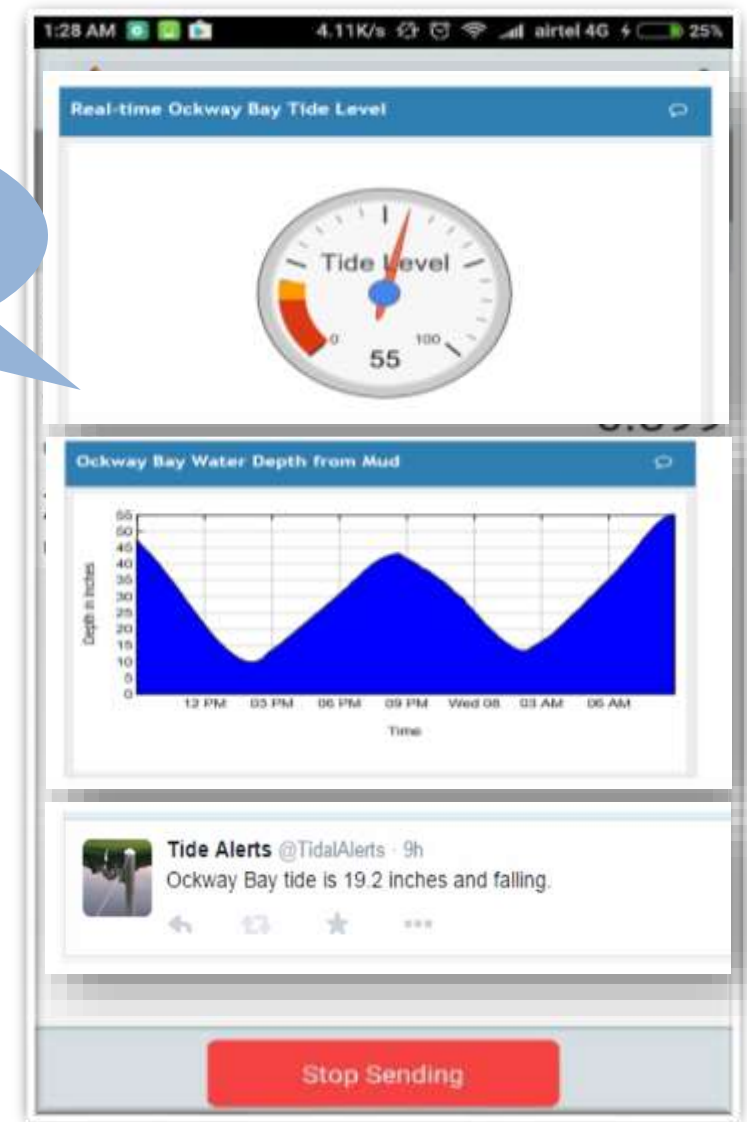
Challenge

Boats get stuck in mud at low tide

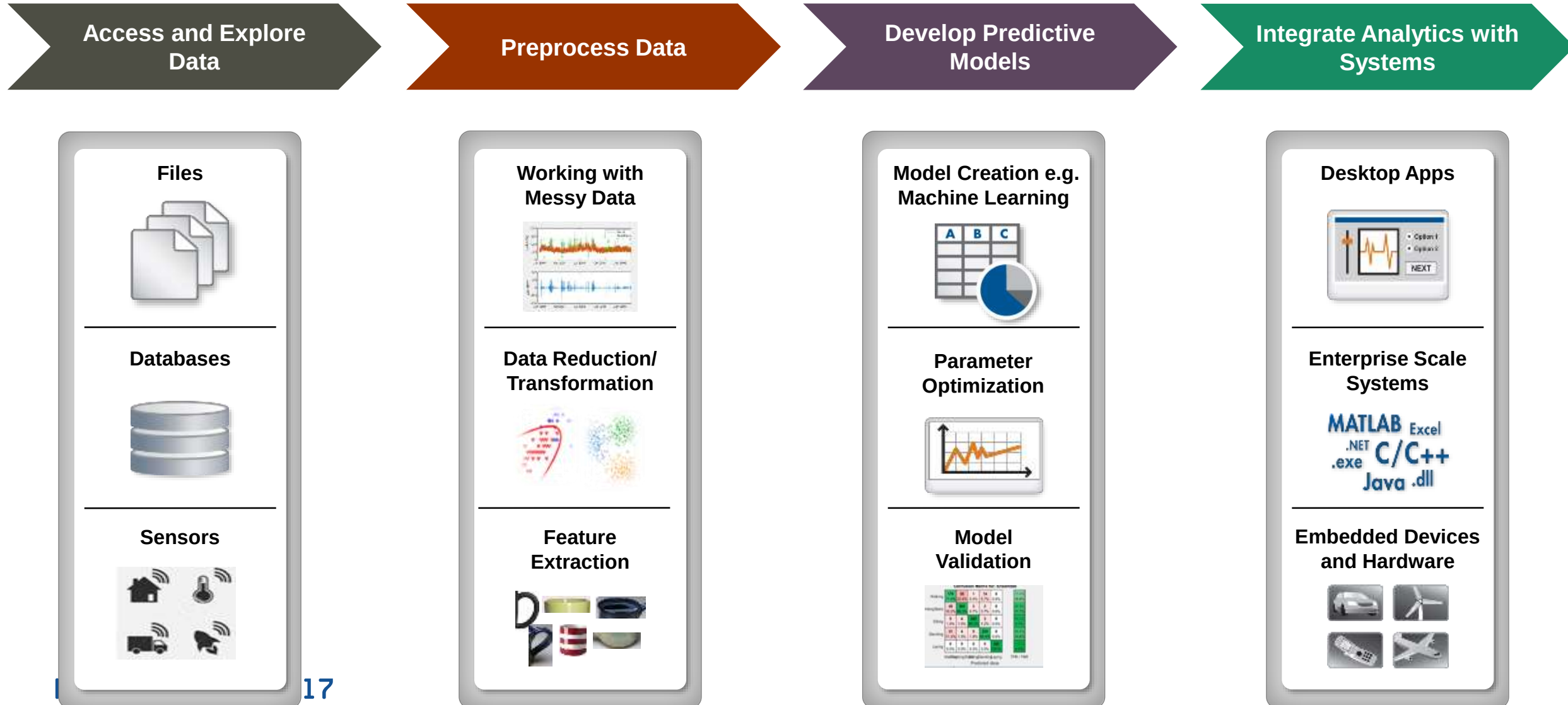
Solution

Advance notification of low tide

Even cooler...to get notifications on mobile



Example 2: Low Tide Prediction - Approach



Example 2: Low Tide Prediction Using MATLAB And ThingSpeak

ThingSpeak™

Channels ▾

Apps

Community

Support ▾

How to Buy

Account ▾

Predicted and Measured Ockway Bay Tide Chart

Un-watch

Tweet

Like 0

Share

Channel ID: 137305

Author: mawrey

Access: Public

Tide measurement and forecasting with the effect of wind predicted using neural networks.

🔑 tide, wind surge, neural network

Data Export

More Information

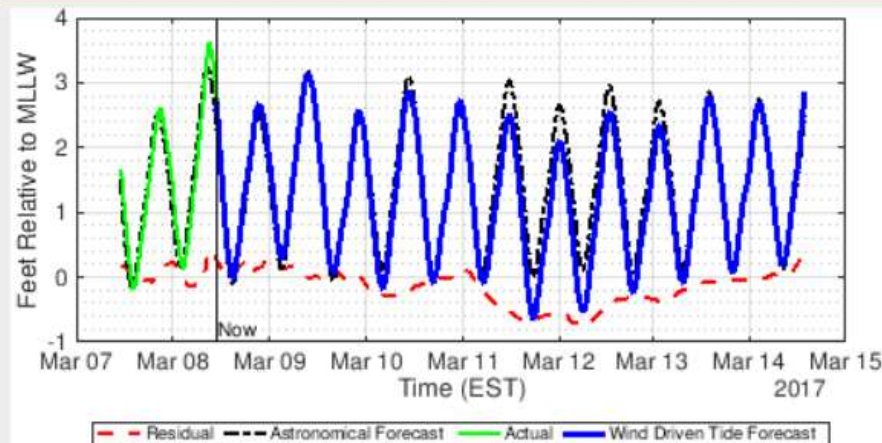
MATLAB Analysis

MATLAB Visualiz

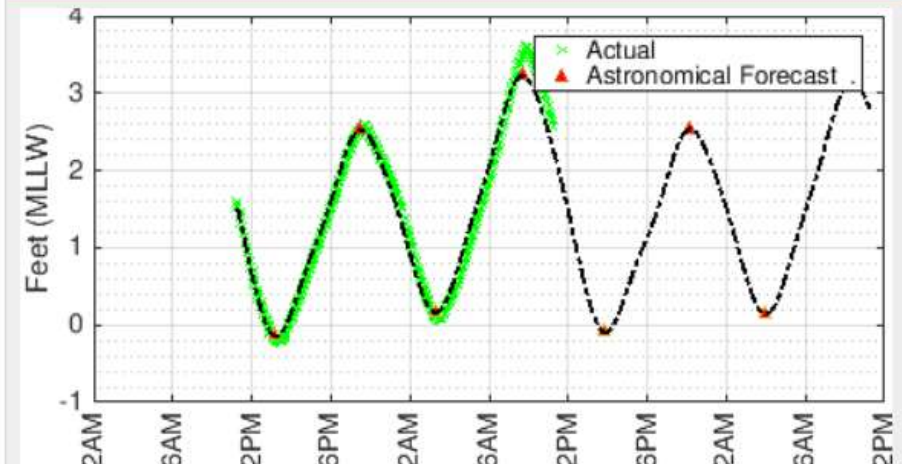
Historical
and Tide



Neural Wind Forecast



Predicted and Measured Ockway Bay Tide Chart



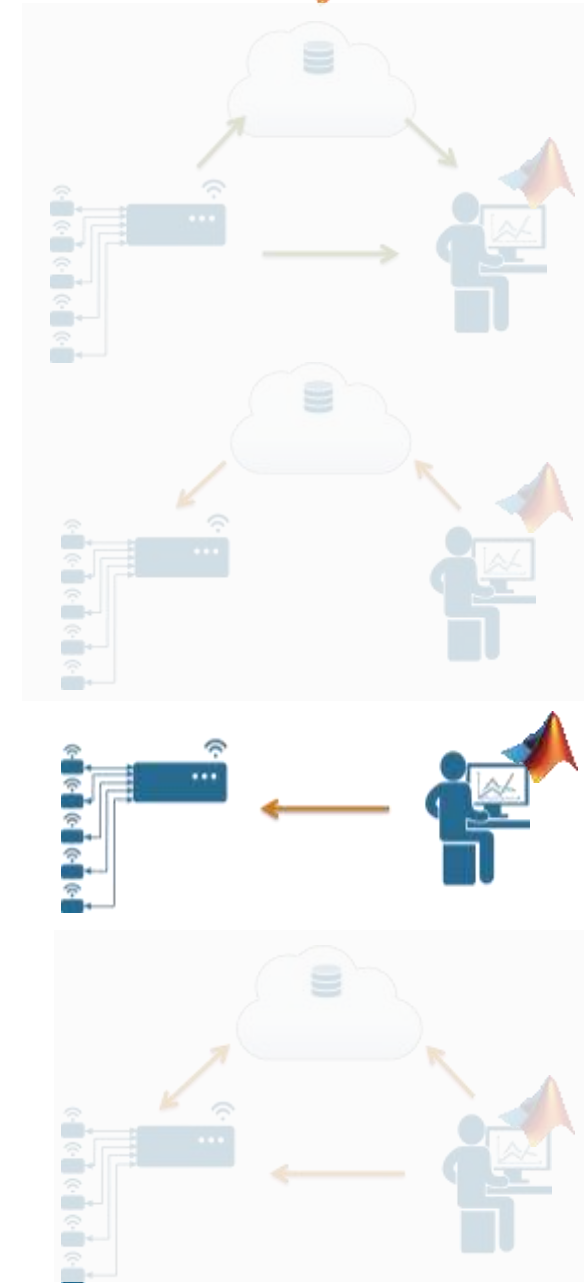
Mar 17
2017

Learn Further: Which Toolboxes Work in ThingSpeak?

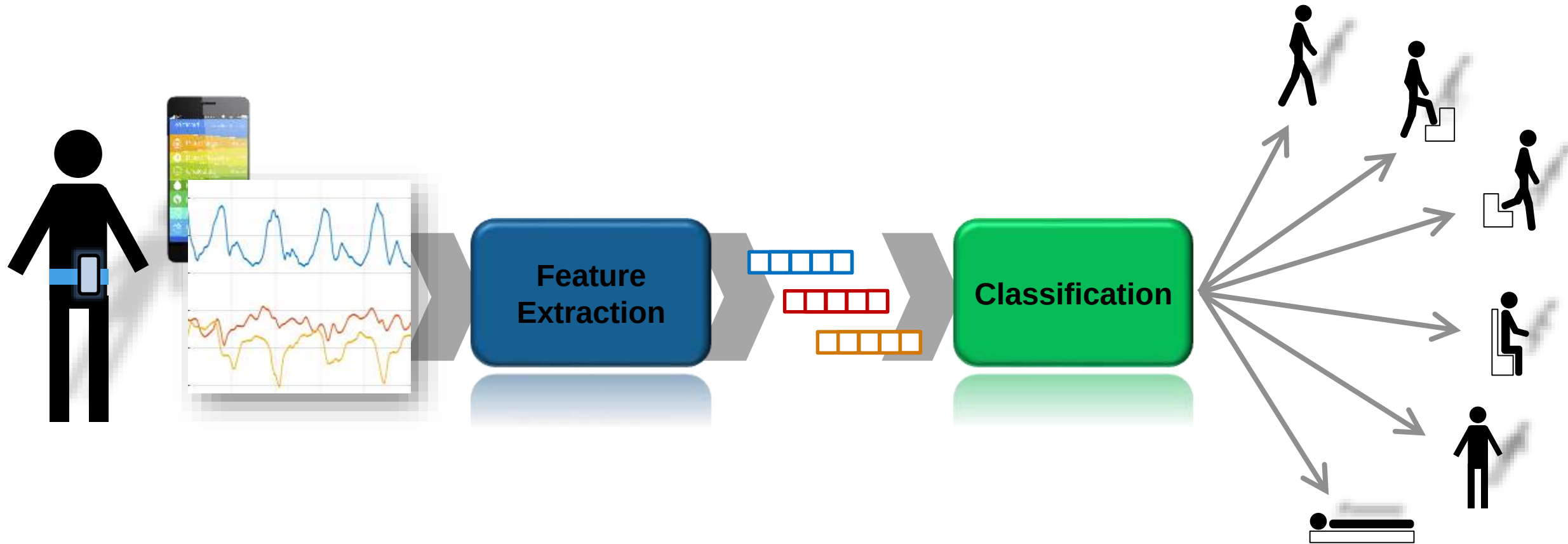
- [Statistics and Machine Learning Toolbox™](#)
- [Curve Fitting Toolbox™](#)
- [Control System Toolbox™](#)
- [Signal Processing Toolbox™](#)
- [Mapping Toolbox™](#)
- [System Identification Toolbox™](#)
- [Neural Network Toolbox™](#)
- [DSP System Toolbox™](#)
- [Datafeed Toolbox™](#)
- [Financial Toolbox™](#)

Examples for Today

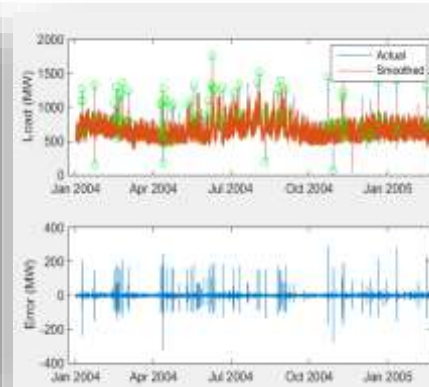
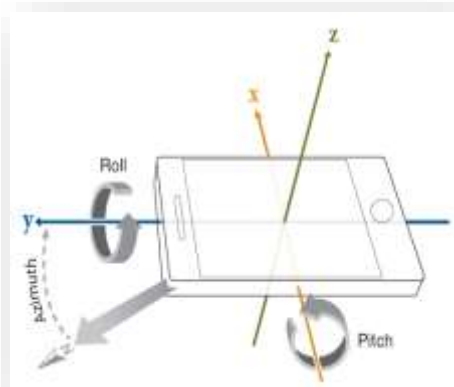
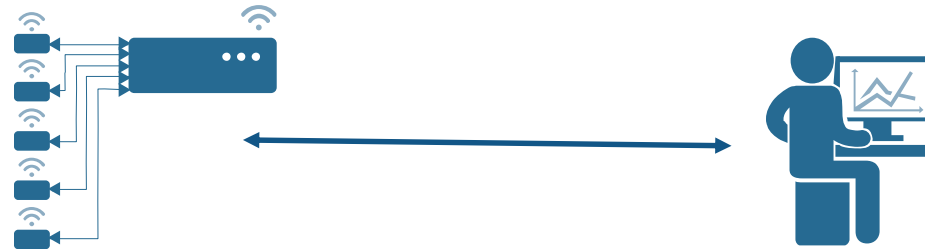
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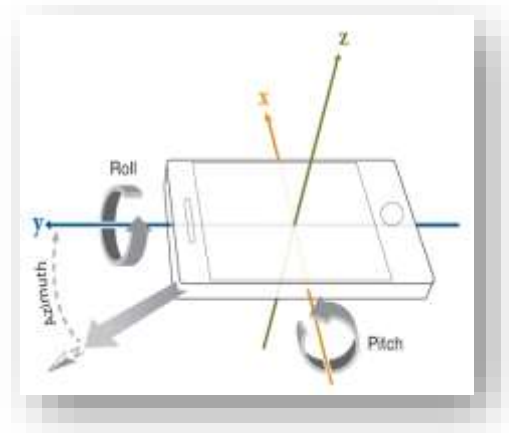
Example 3: Sensor Analytics and Development of Smart Connected Devices



Example 3: Sensor Analytics and Development of Smart Connected Devices - workflow



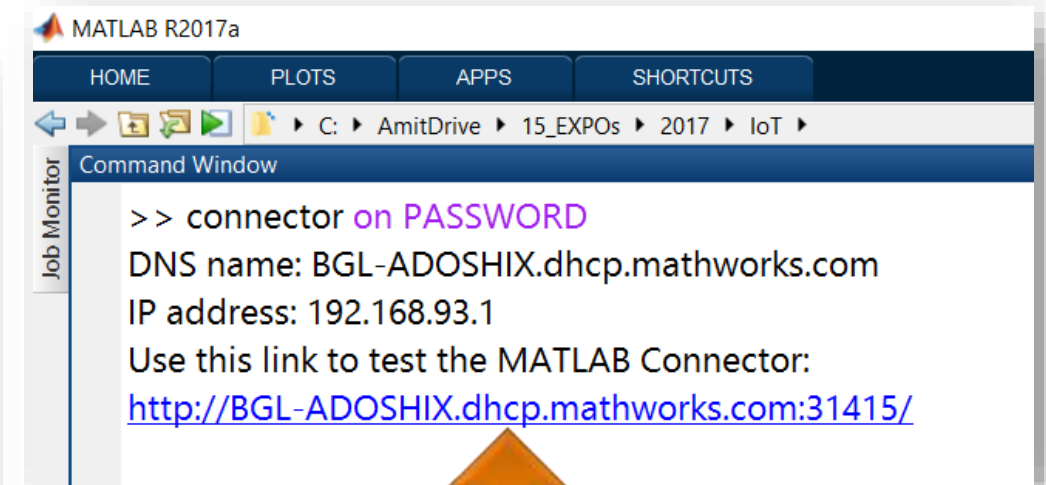
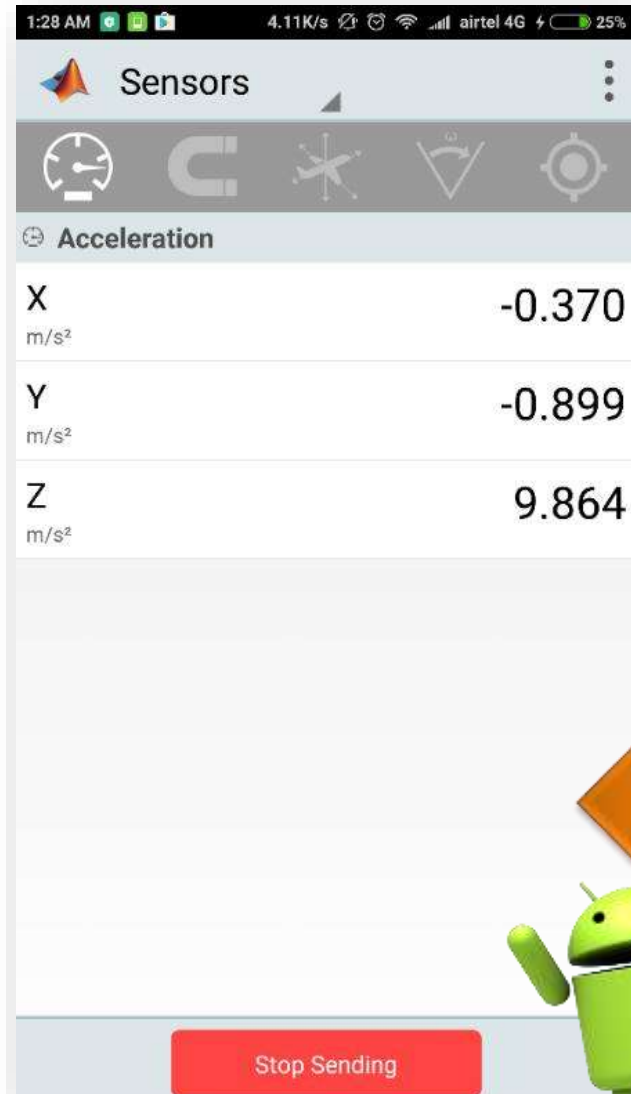
Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow



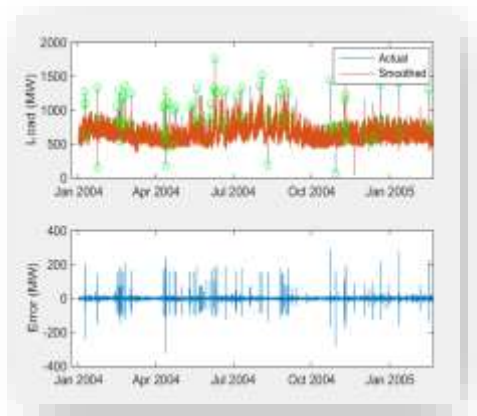
Connect and Acquire

1

MATLAB EXPO 2017

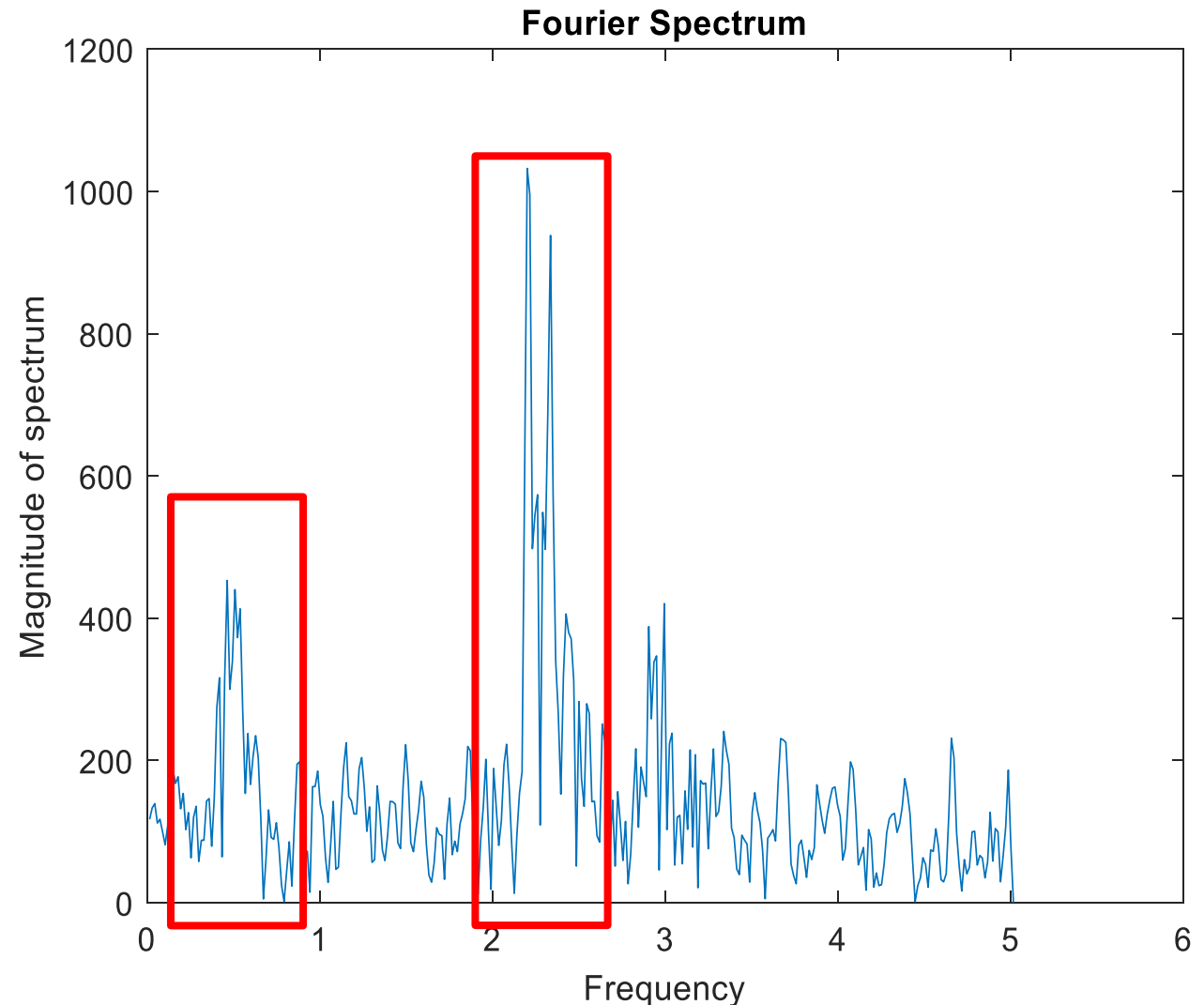
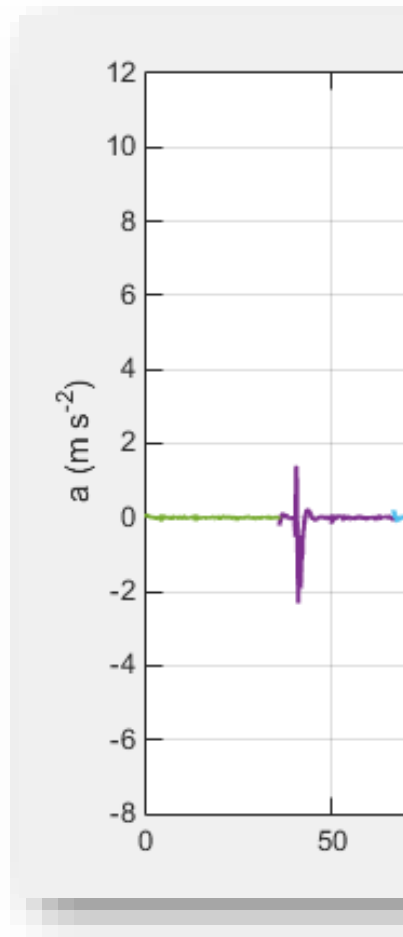


Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow



**Signal
Processing and
feature extraction**

2



Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow



Machine Learning

3

File Explorer:

Name	Size	Type
plotModelResul...	4 KB	Function
saveSensorData...	4 KB	Function
plotActivityResu...	4 KB	Function
plotRawSensor...	2 KB	Function
downloadSens...	2 KB	Function
Wpca1.m	1 KB	Function
Wstd.m	1 KB	Function
Wmean.m	1 KB	Function
Script		
Human_Activity...	3 KB	Script
OpeningExempl...	1 KB	Script
MAT-file		
rawSensorData_...	41.15 MB	MAT-file
rawSensorData_...	16.49 MB	MAT-file
OpeningExempl...	2.32 MB	MAT-file

Code Editor (Human_Activity_Learning.m):

```

1  %% Human Activity Learning Using Mobile Phone Data
2  % Human activity sensor data contains observations derived from
3  % sensor measurements taken from smartphones worn by people while doing
4  % different activities (walking, lying, sitting etc). The goal of this
5  % example is to provide a strategy to build a classifier that can
6  % automatically identify the activity type given the sensor measurements.
7  %
8  % Copyright (c) 2015, MathWorks, Inc.
9
10 %% Load Raw Sensor Data for training
11 load rawSensorData_train.mat
12
13 %% Display data summary
14 plotRawSensorData(total_acc_x_train, total_acc_y_train, ...
15                   total_acc_z_train, trainActivity, 1000)
16

```

Command Window:

```

fx >>

```

Workspace:

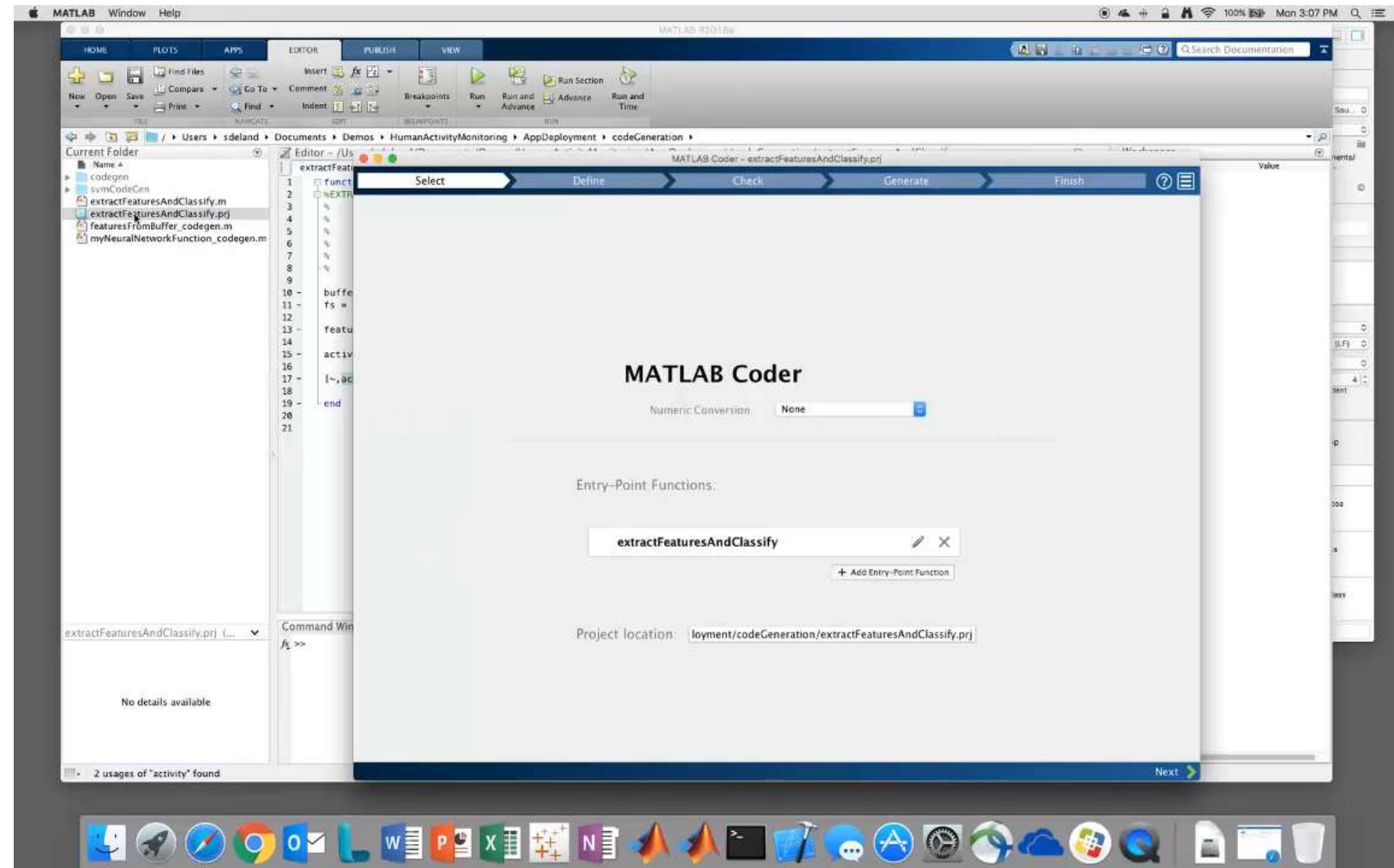
Name	Value
body_gyro_x_train	7352x128 double
body_gyro_y_train	7352x128 double
body_gyro_z_train	7352x128 double
humanActivityData	7352x19 table
rawSensorDataTrain	7352x6 table
T_mean	7352x6 table
T_pca	7352x6 table
T_stdv	7352x6 table

Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow



Embedded
Implementation

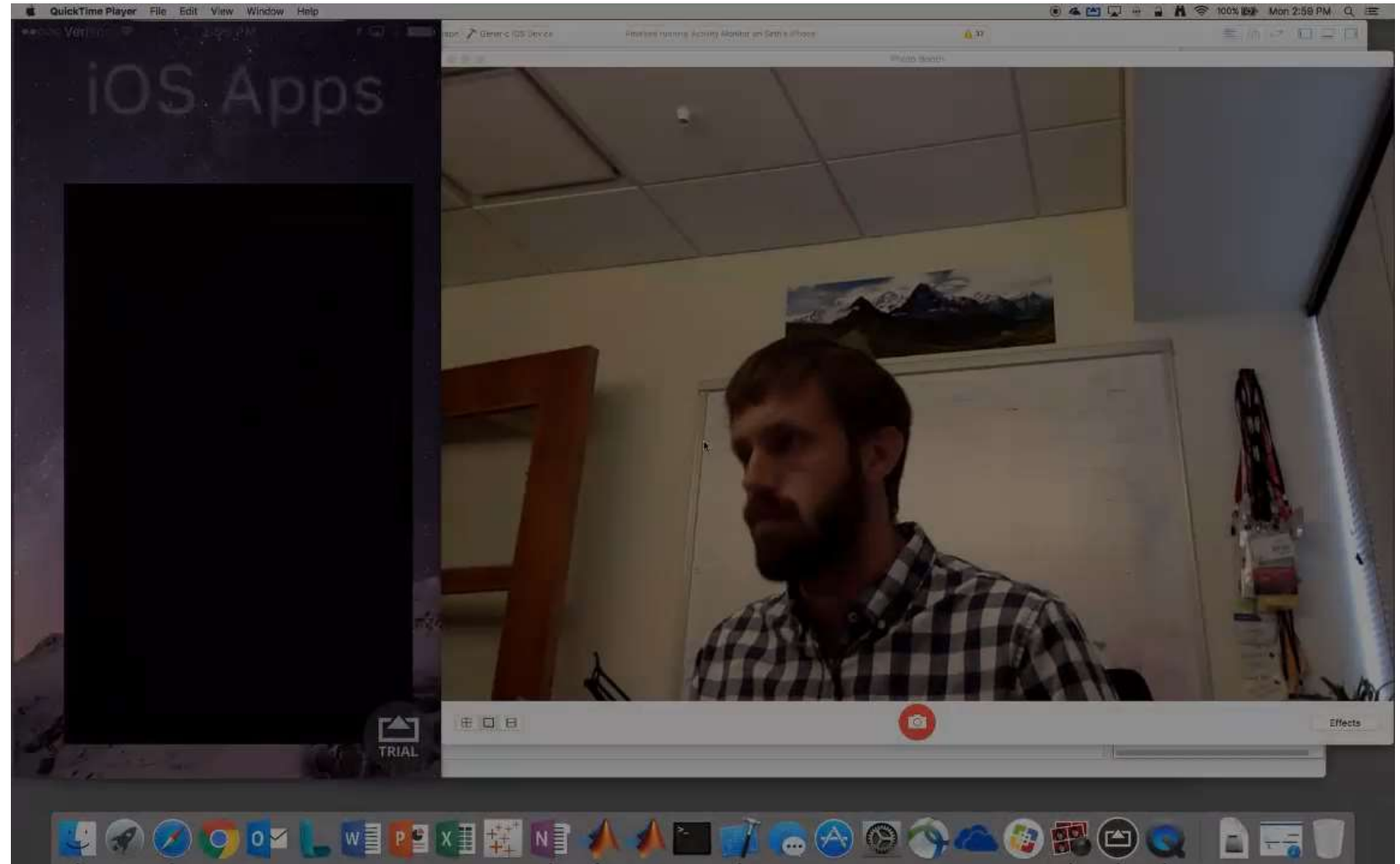
4



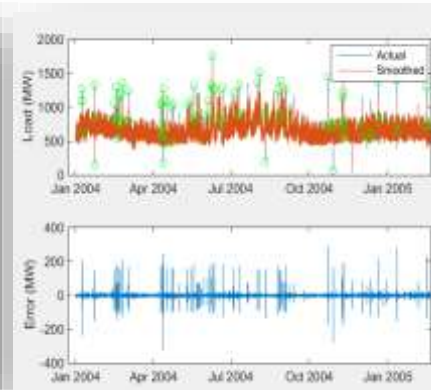
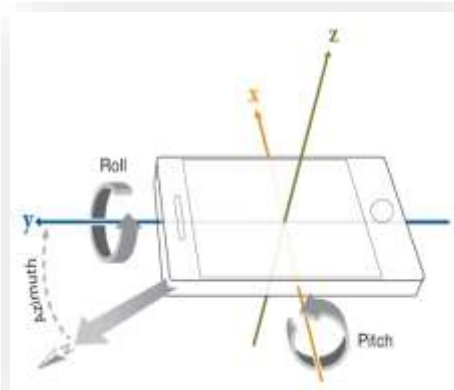
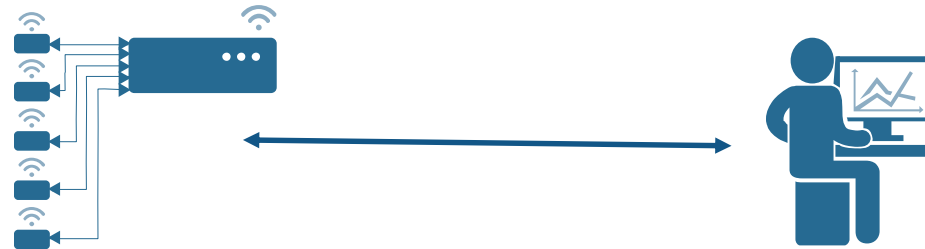
Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow



App in action



Example 3: Summary of Sensor Analytics Development and Deployment



Connect and Acquire

Signal
Processing

Machine
Learning

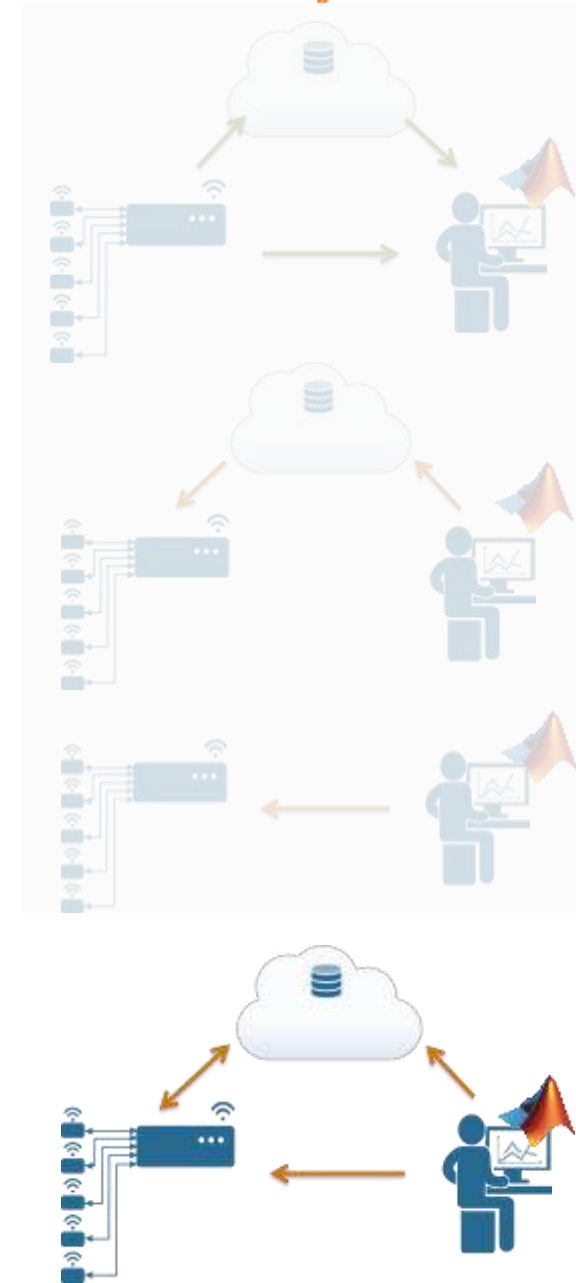
Embedded
Implementation

Code Generation using MathWorks Product

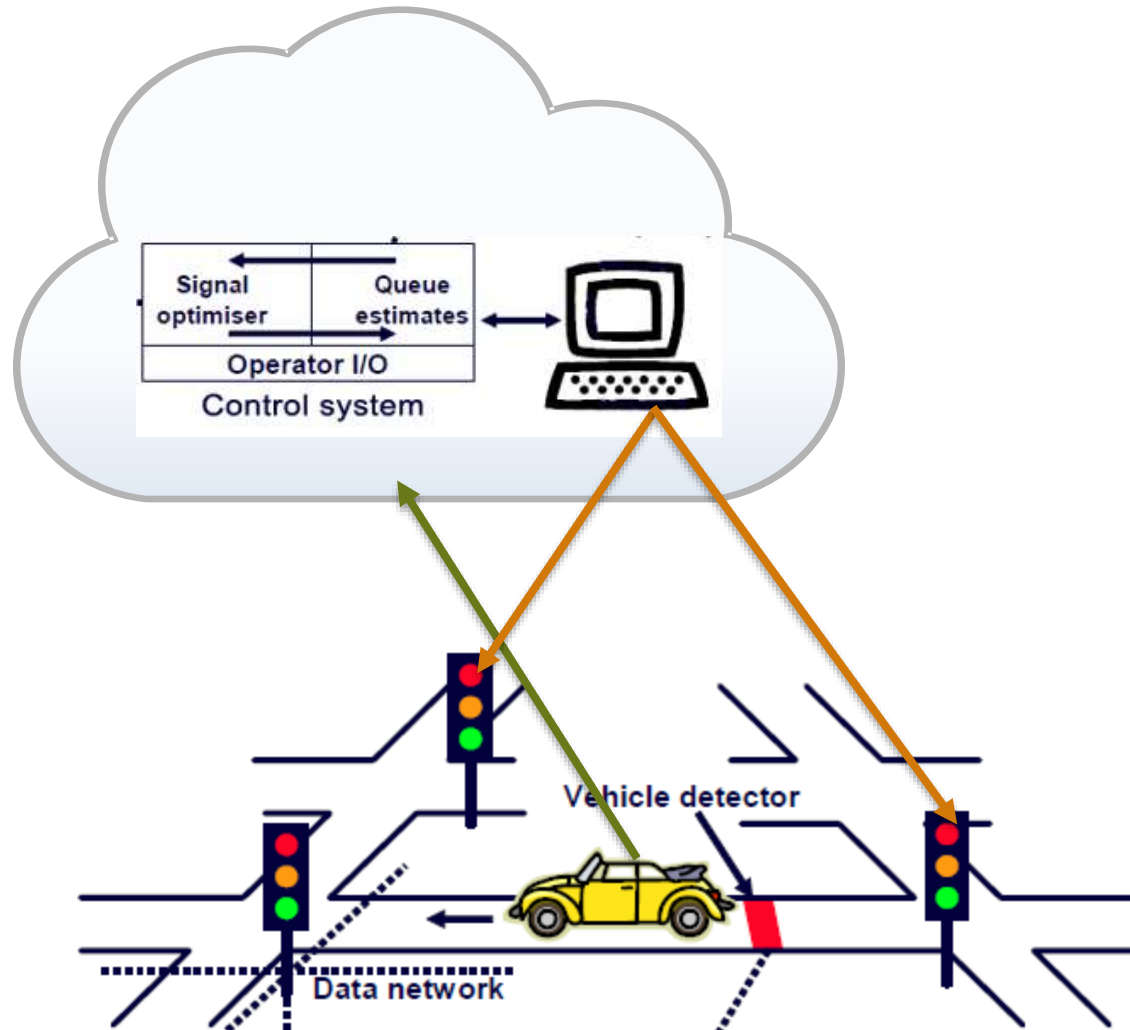
*“Embedded Coder generated C code that was **error-free and efficient**—so much so that the team only needed to write code for our device drivers. This **saved us 6 months of development time**.” - Dr. Christian Robl, System Architect at Vodafone Group R&D.*

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Example 4: Traffic monitoring can be used for smart traffic light management



Example 4: Traffic Monitoring

Objectives

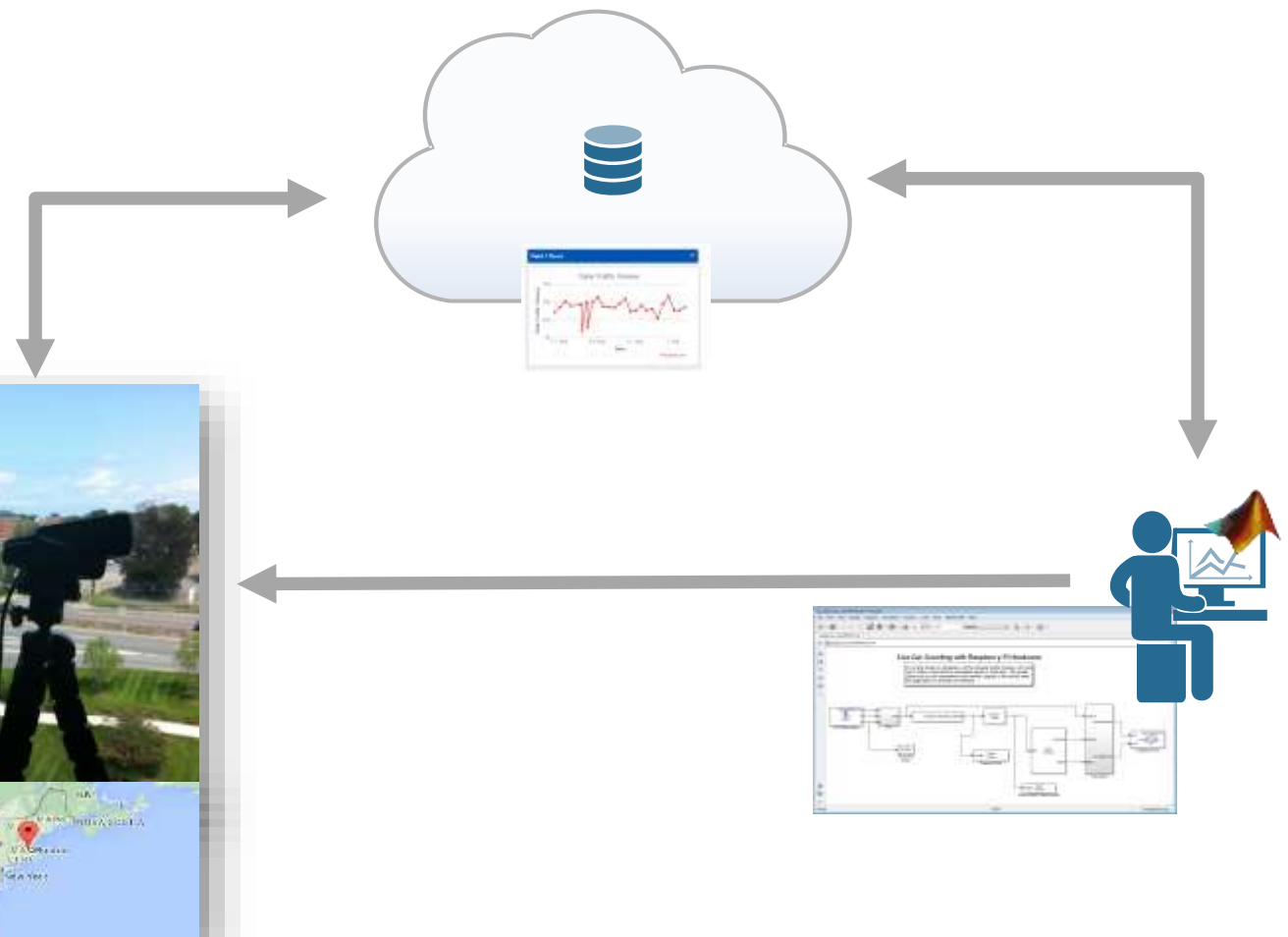
- Measure, explore, discover traffic patterns
- Provide live local traffic information service

Solution

- RaspberryPi + webcam
- **Automated deployment of vision algorithms on embedded sensor**
- Full example available at makerzone.makelabs.com



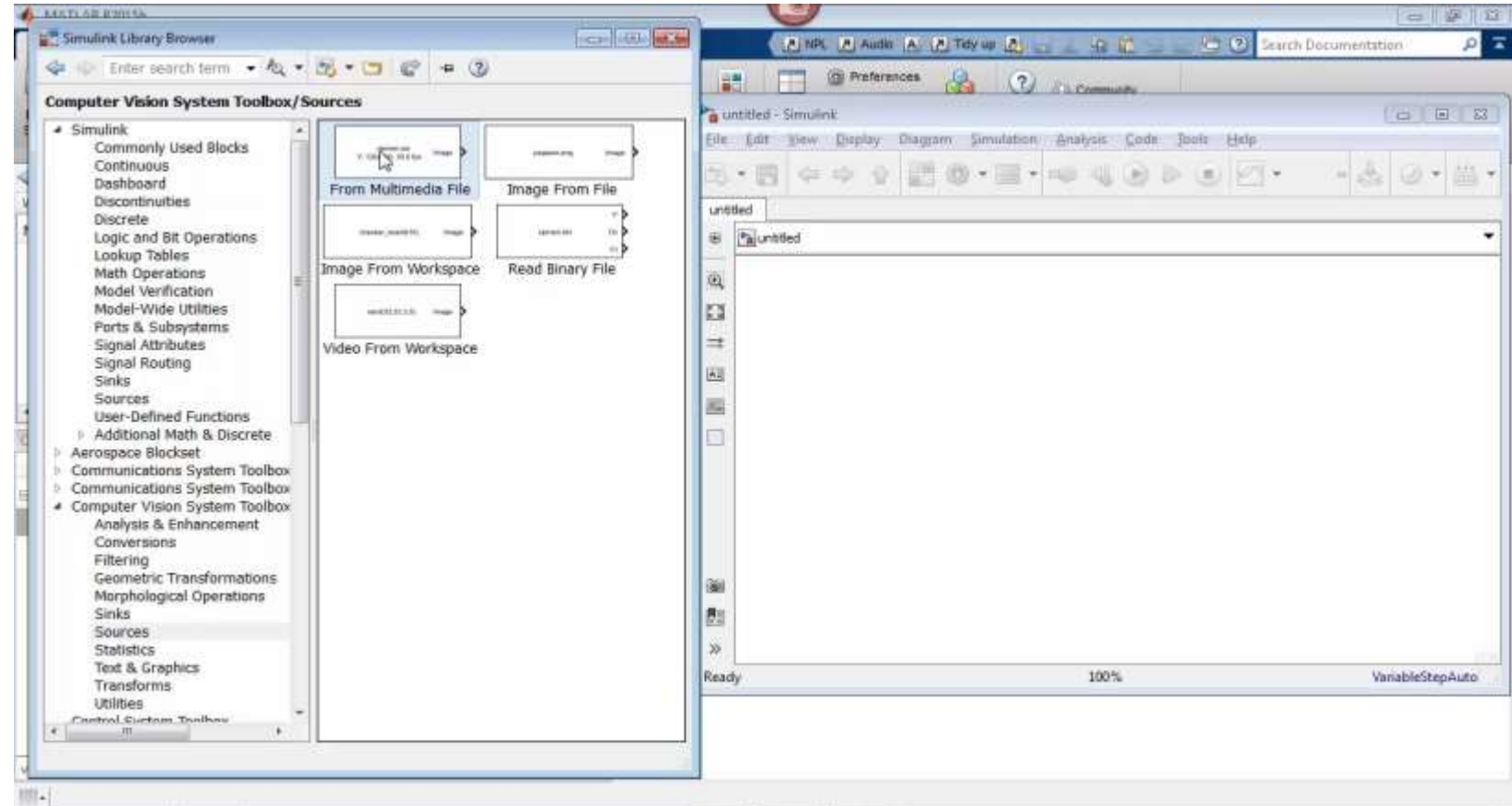
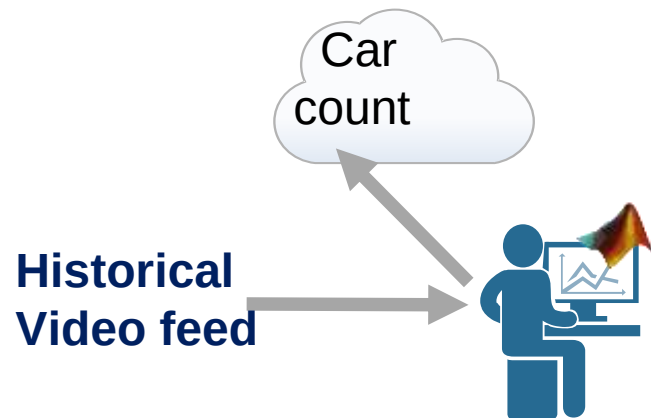
Cloud needs only car count and not all video data



Example 4: Traffic Monitoring - Approach

Step 1: Prototyping

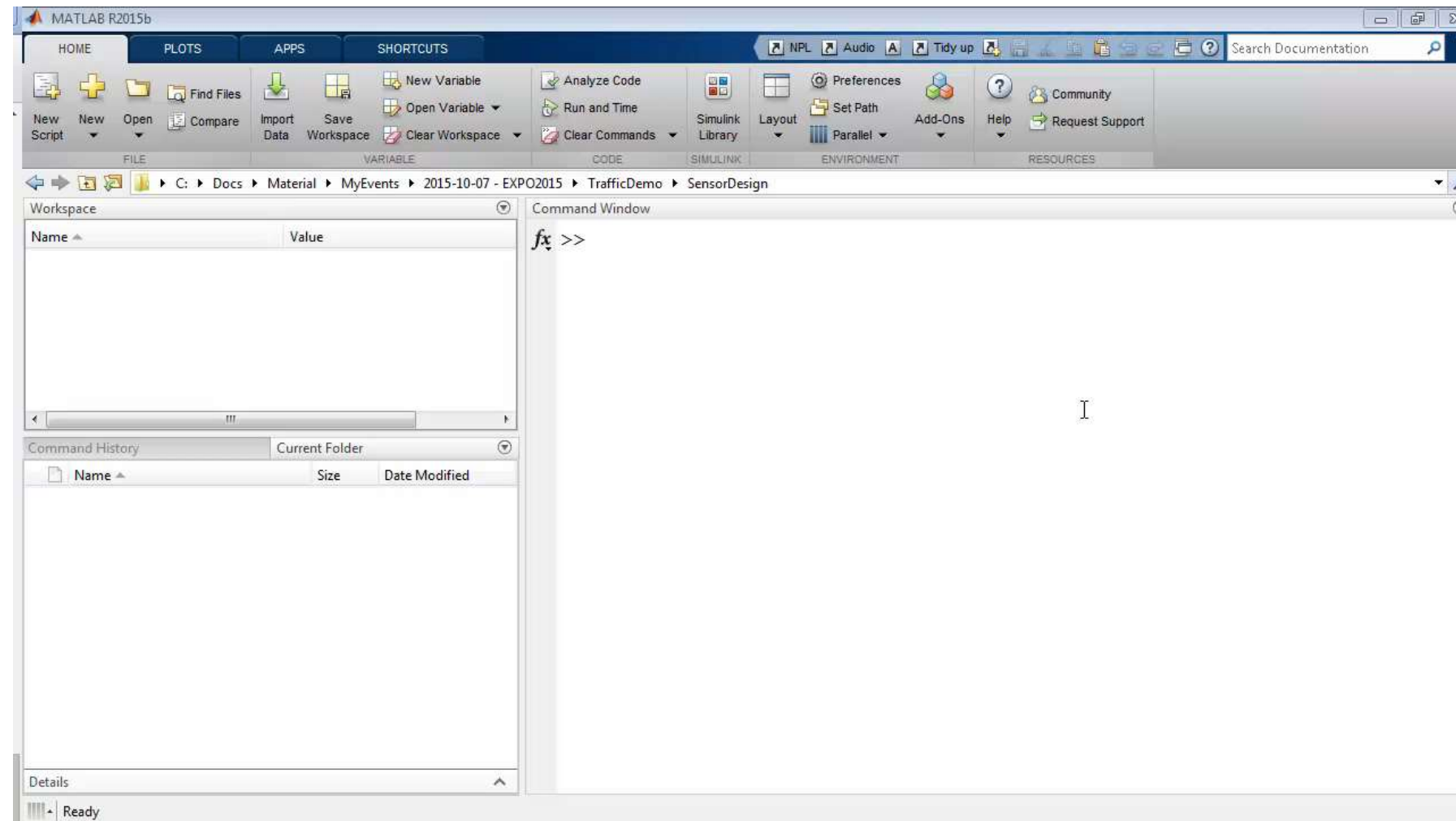
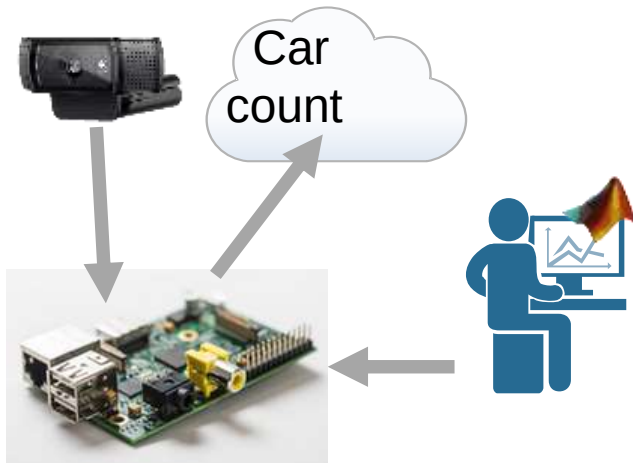
- Create a prototype in Simulink and develop a logic
- Just Simulink and a camera feed



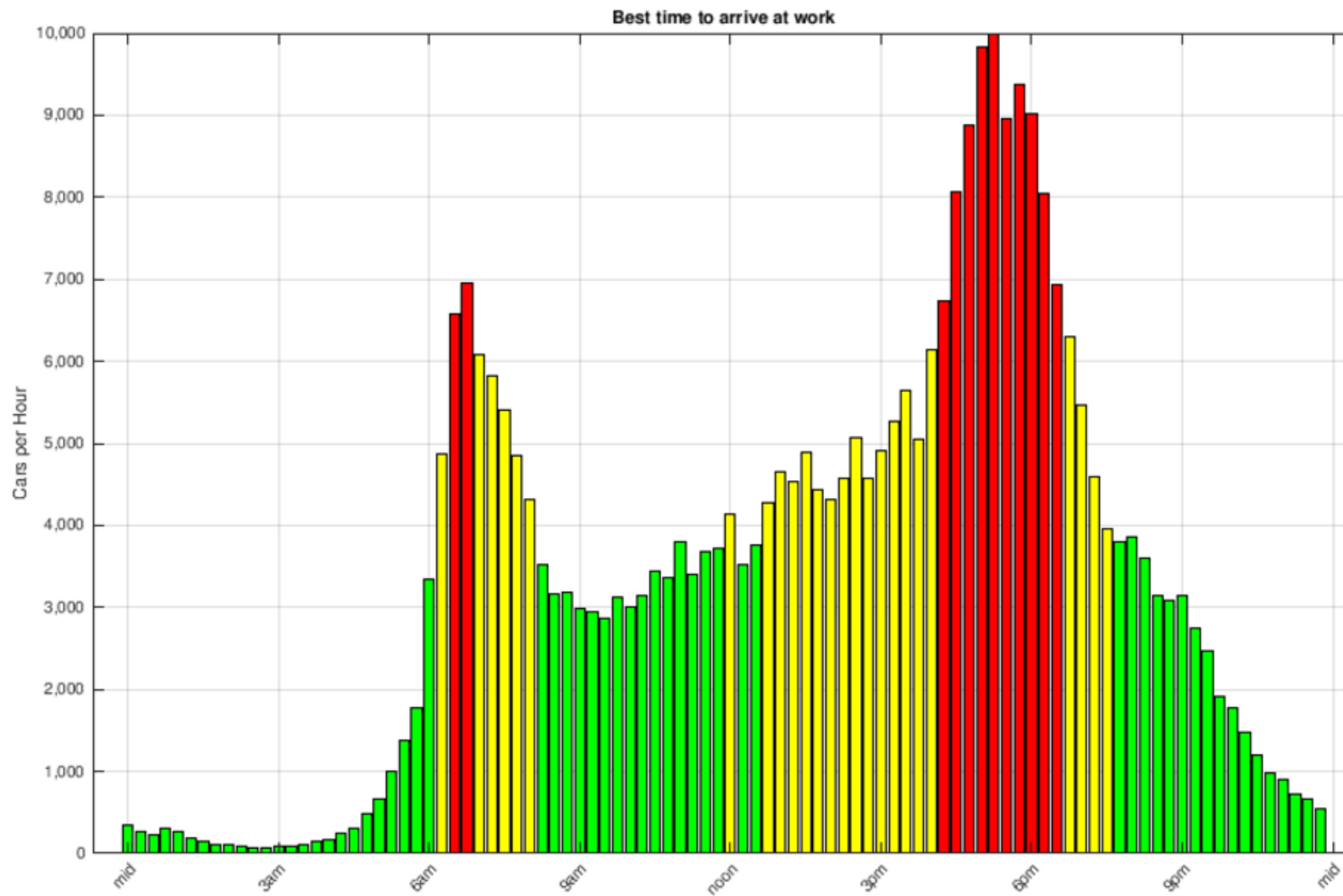
Example 4: Traffic Monitoring - Approach

Step 2: Port it to Raspberry Pi

- Use the code generation capabilities of Simulink to deploy this algorithm onto the Raspberry Pi

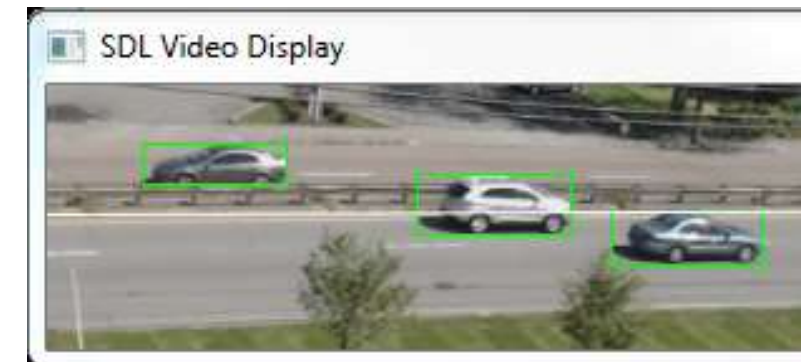


From Data to Insight



**When should I
start for home?**

**Well, I better start early
from office or stay back
late in the office**



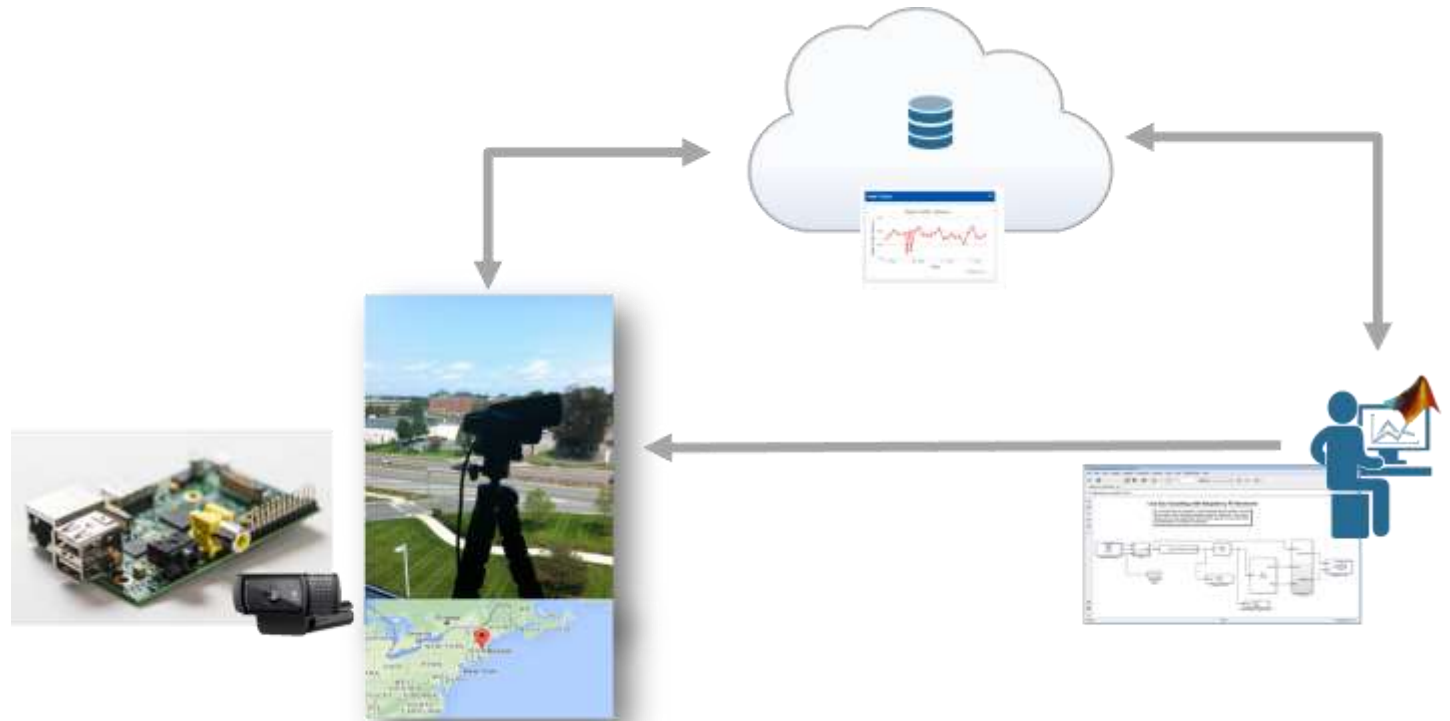
Example 4: Summary – Developing smart devices

Step 1: Prototyping

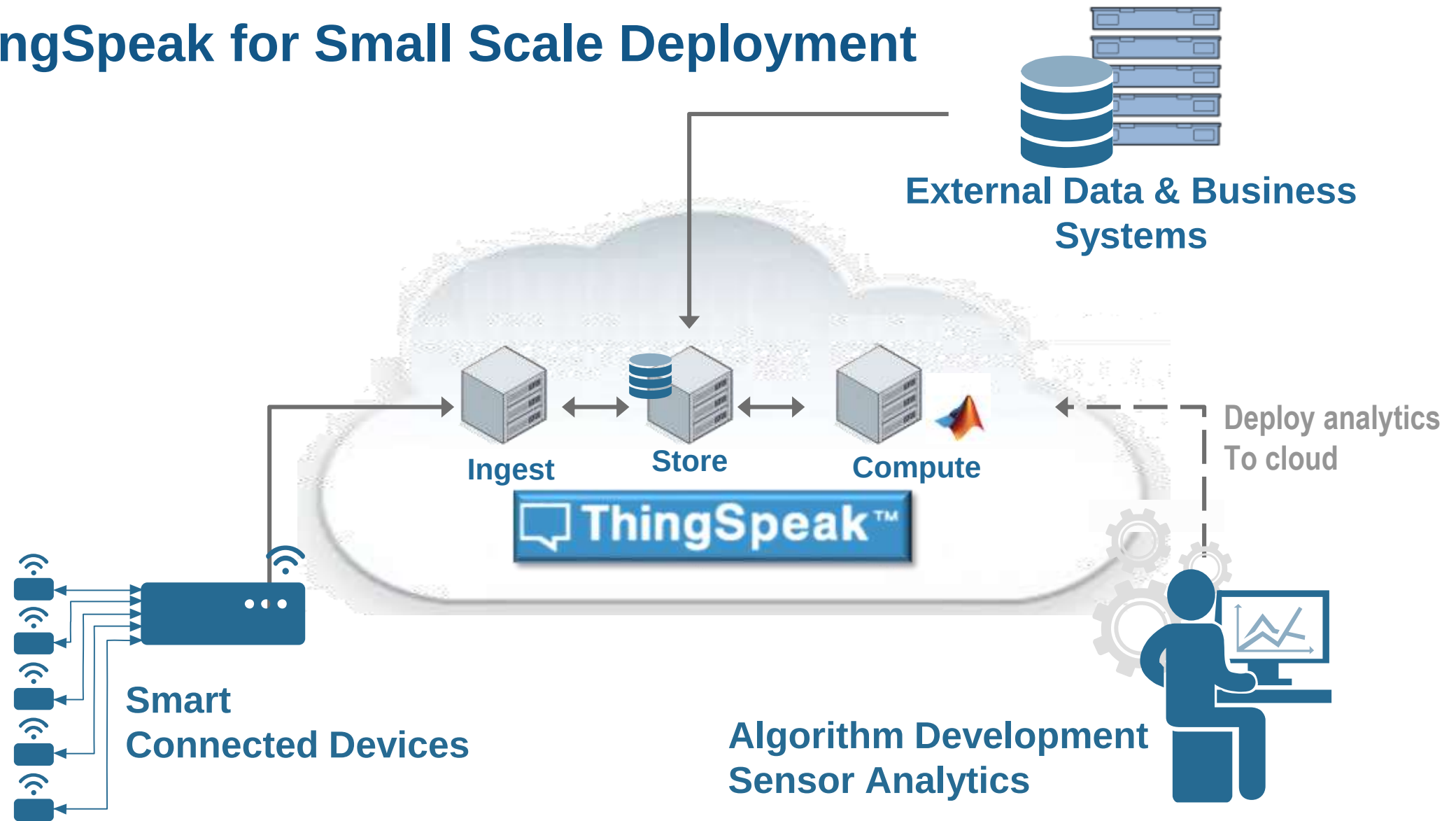
- Create a prototype in Simulink and develop a logic and send count to cloud
- Need only Simulink and a camera feed to start with

Step 2: Port it to Raspberry Pi

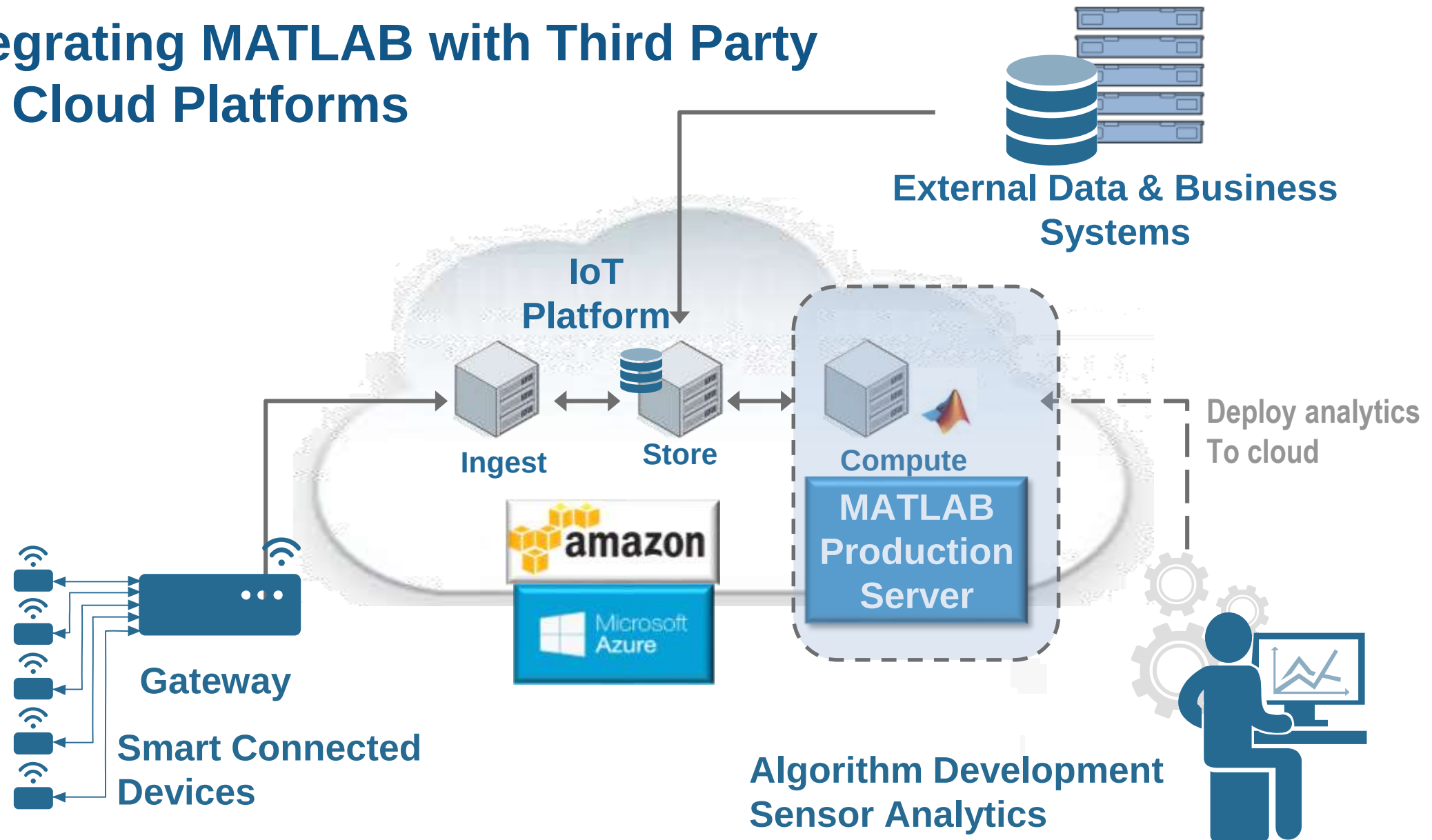
- Use the code generation capabilities of Simulink to deploy this algorithm onto the Raspberry Pi



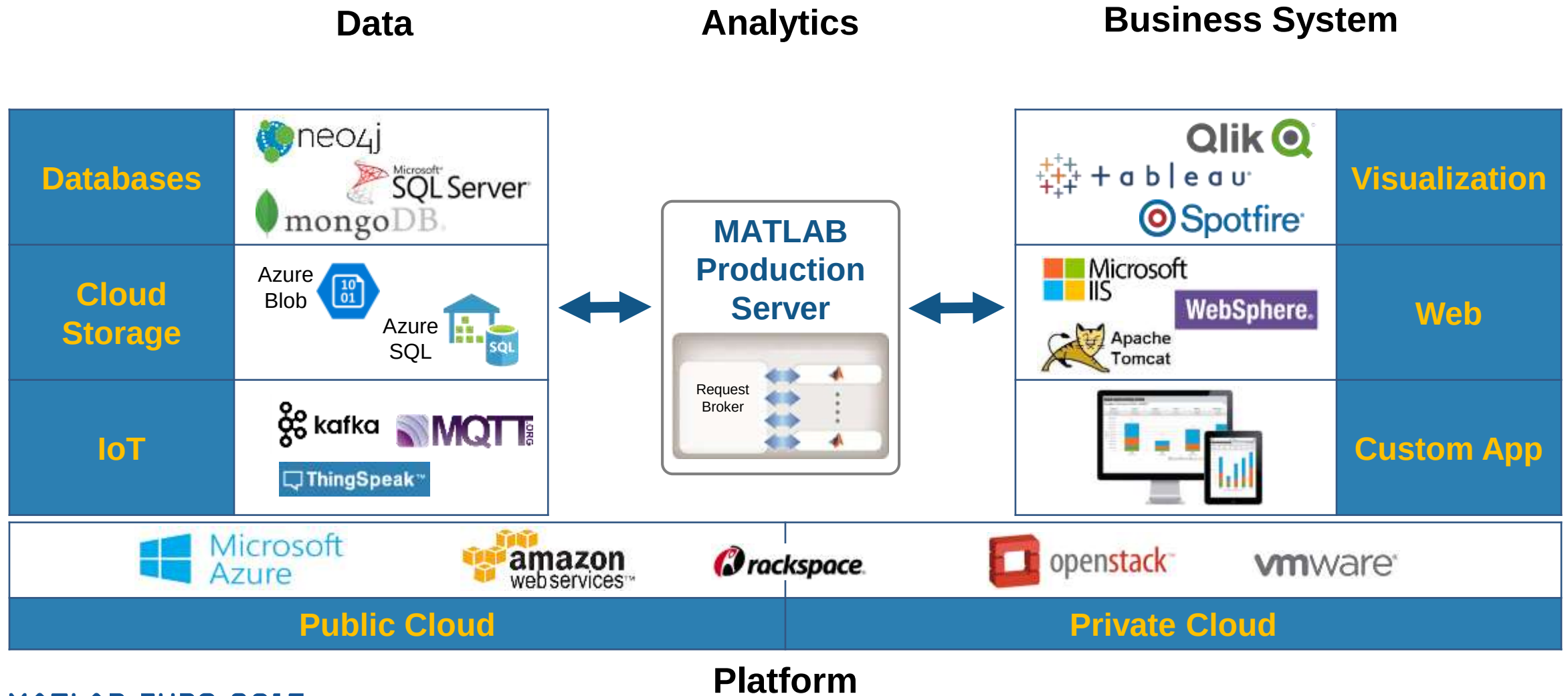
ThingSpeak for Small Scale Deployment



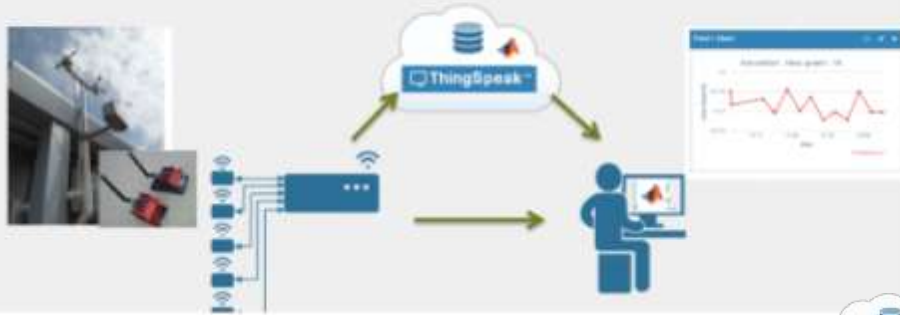
Integrating MATLAB with Third Party IoT Cloud Platforms



Integrating MATLAB in Large Scale Production Systems



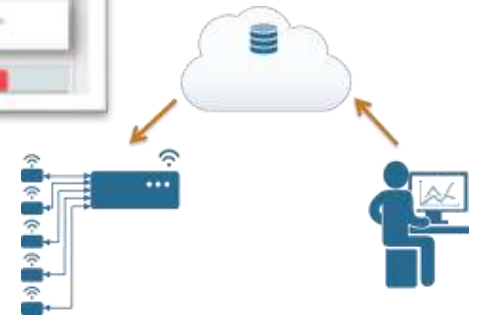
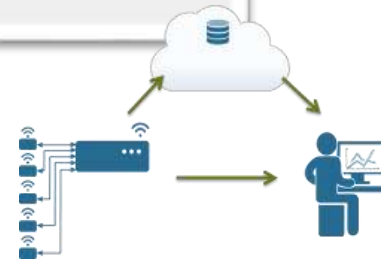
Example 1: Weather monitoring using ThingSpeak and MATLAB



Example 2: Low Tide Prediction Using MATLAB And ThingSpeak

Challenge
Boats get stuck in mud at low tide

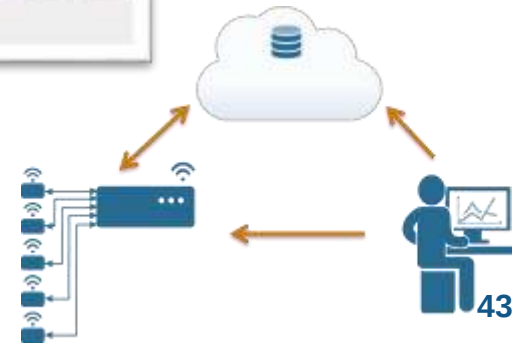
Solution
Advance notification of low tide



Example 3: Human Activity Analysis and Classification

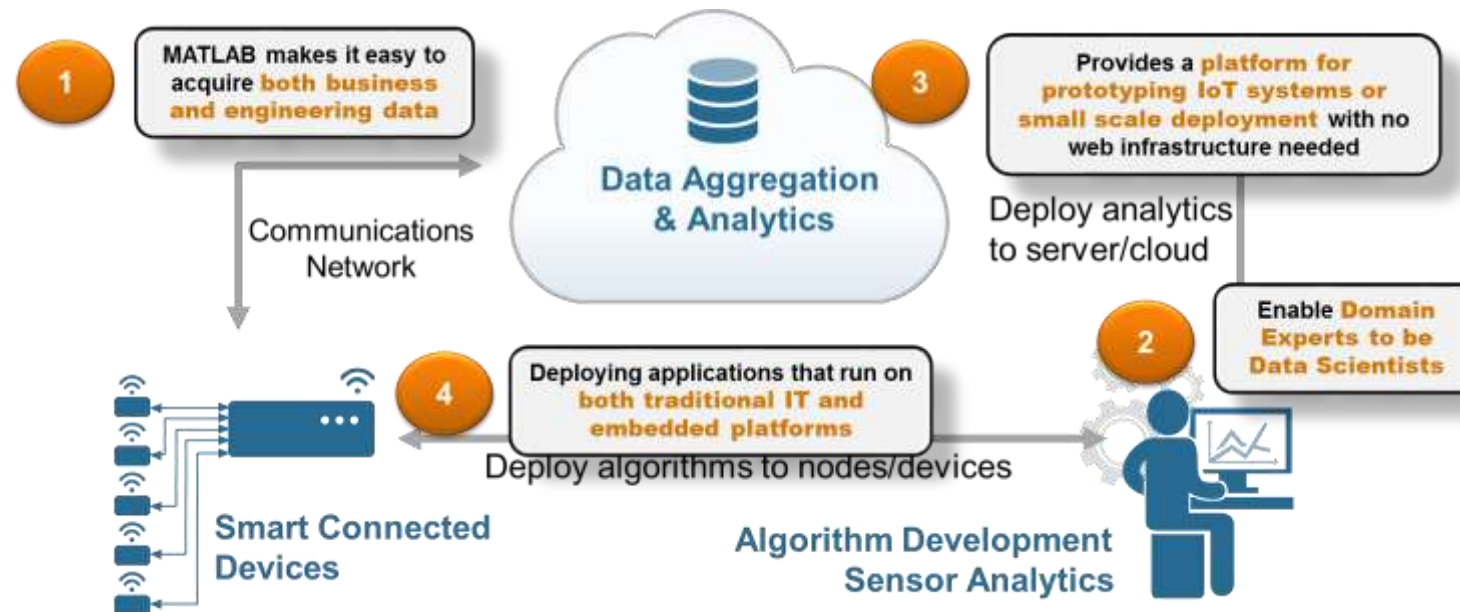


Example 4: Traffic monitoring can be used for smart traffic light management



MathWorks Addresses IoT Challenges

- Quickly **collect and analyze** IoT data with **ThingSpeak** and **MATLAB**
- **Develop analytics** algorithms using **MATLAB** and **toolboxes**
- **Deploy on smart devices** using code generation and embedded target support
- **Deploy on cloud** using **ThingSpeak** and MATLAB Production Server



What You Can Do to Learn More

- [Log-in to ThingSpeak with your MathWorks account and explore](#)
- [View a webinar on Machine Learning with MATLAB](#)
- [Read a Technical Article on Forecasting Tides with MATLAB](#)
- [Read a tutorial on how to send data to ThingSpeak over MQTT](#)



The screenshot shows the MathWorks ThingSpeak website. At the top is the MathWorks logo. Below it is a blue header with the word "ThingSpeak" in white. Under the header is a "CONTENTS" section with a hamburger menu icon. The main content area is titled "Getting Started with ThingSpeak" in orange. Below this title are links for "Product Description" and "System Requirements". Further down is a "Tutorials" section with three entries: "Collect Data in a New Channel" (Learn how to create a channel, collect data and write it to a new channel.), "Analyze Your Data" (Learn how to analyze and visualize data using MATLAB®.), and "Act on Your Data" (Set threshold limits on data to send a tweet under certain conditions.).

MathWorks Training Offerings

Machine Learning with MATLAB

INTERMEDIATE

This two-day course focuses on data analytics and machine learning techniques in MATLAB using functionality within Statistics and Machine Learning Toolbox™ and Neural Network Toolbox™.

The course demonstrates the use of unsupervised learning to discover features in large data sets and supervised learning to build predictive models. Examples and exercises highlight techniques for visualization and evaluation of results. Topics include:

- Importing and organizing data
- Finding natural patterns in data
- Building predictive models
- Evaluating and improving the model

Prerequisites: *MATLAB Fundamentals*

Interfacing MATLAB with C Code

INTERMEDIATE

This one-day course covers details of interfacing MATLAB with user-written C code. Topics include:

- Source MEX-files
- Data exchange between MATLAB and MEX-files
- The MATLAB engine interface

Prerequisites: *MATLAB Fundamentals* and a basic working knowledge of the C programming language

<http://www.mathworks.com/services/training/>



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