

MATLAB EXPO 2016

Design Challenges for Sensor Data Analytics in Internet of Things (IoT)

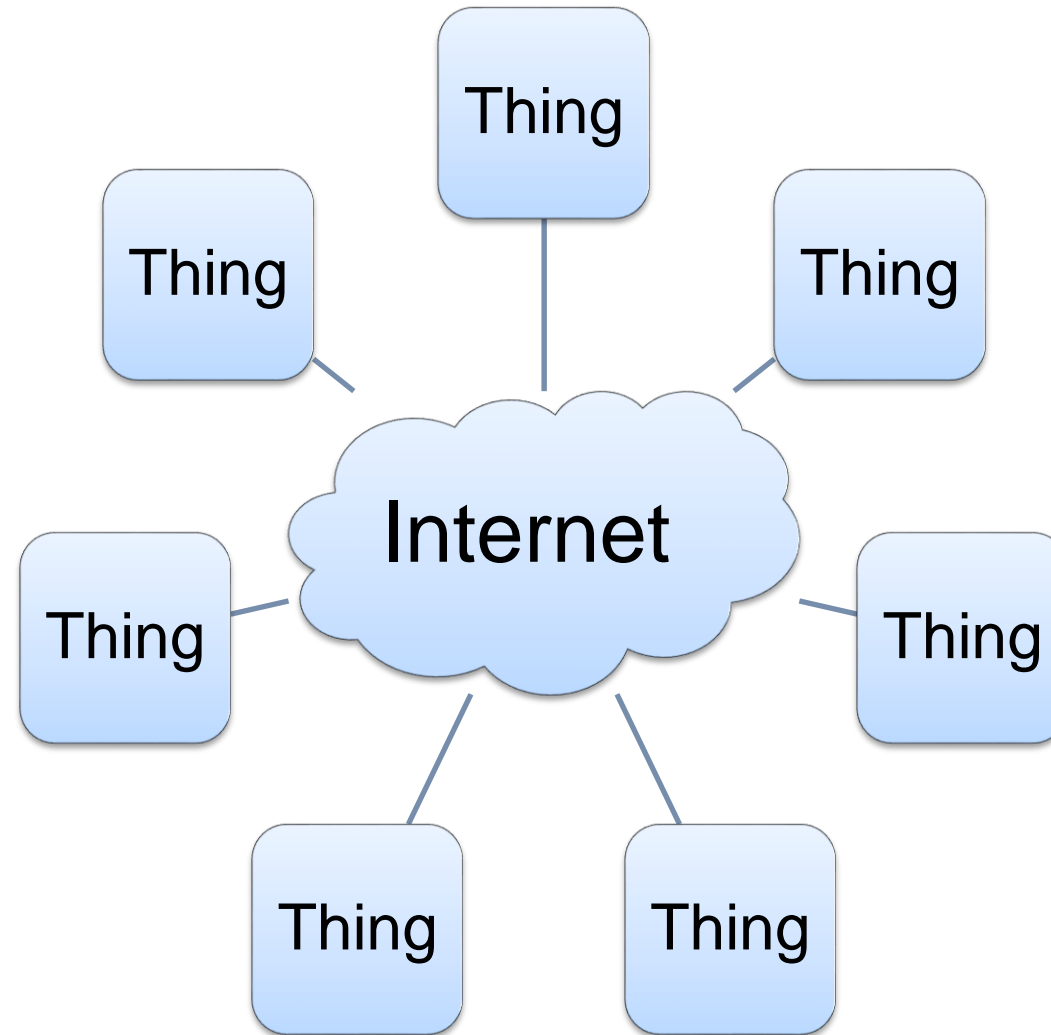
Corey Mathis



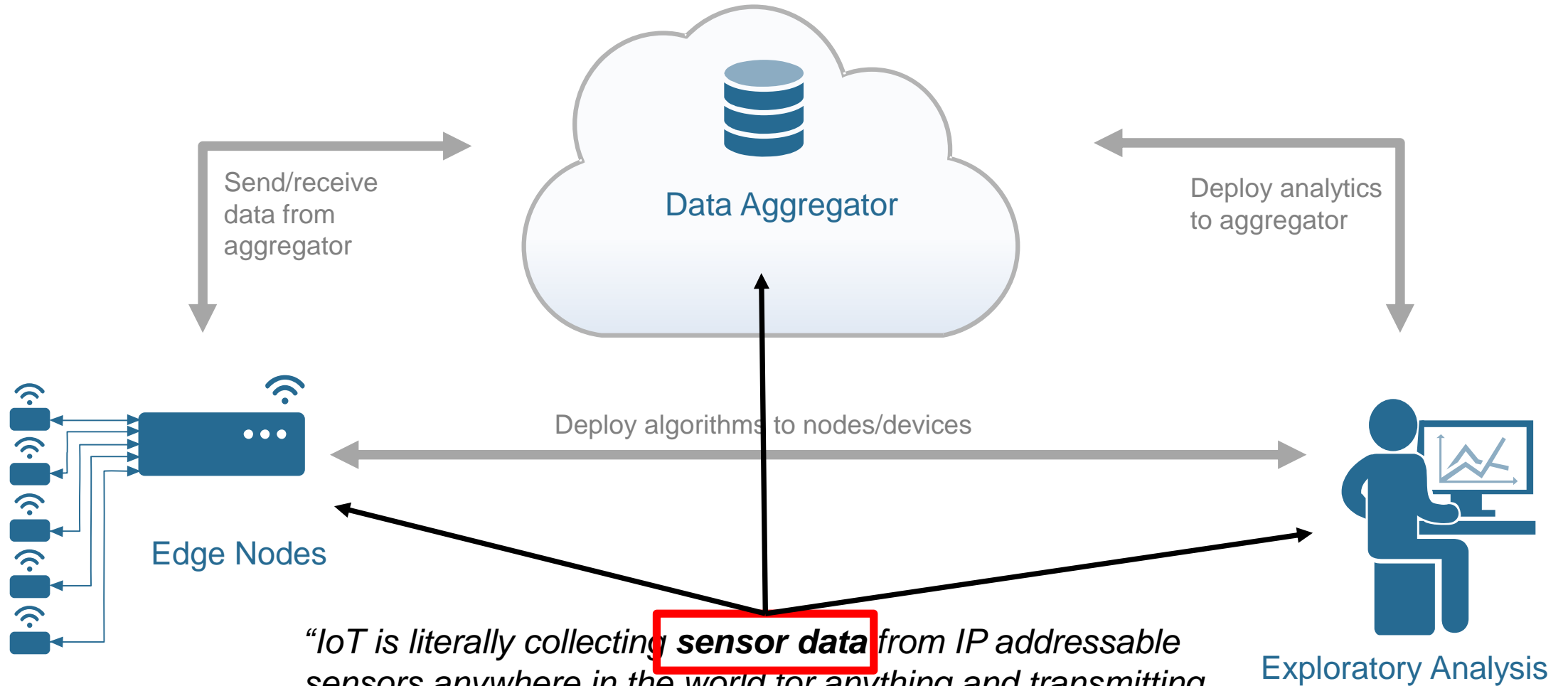
Agenda

- <Brief> IoT Overview
- Design Challenges for Sensor Data Analytics
- Example Solutions

What is the Internet of Things?



What is the Internet of Things?

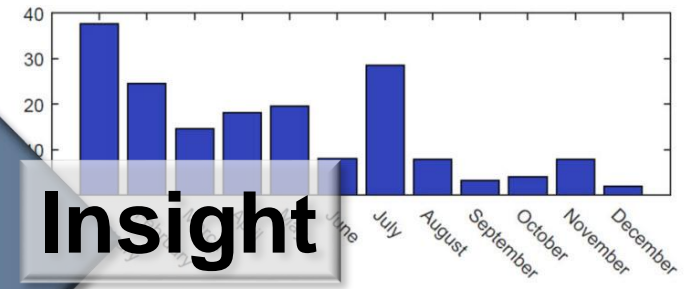
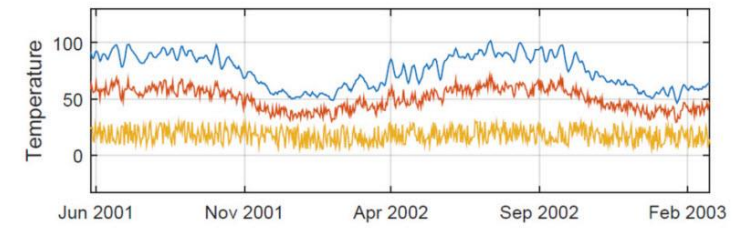
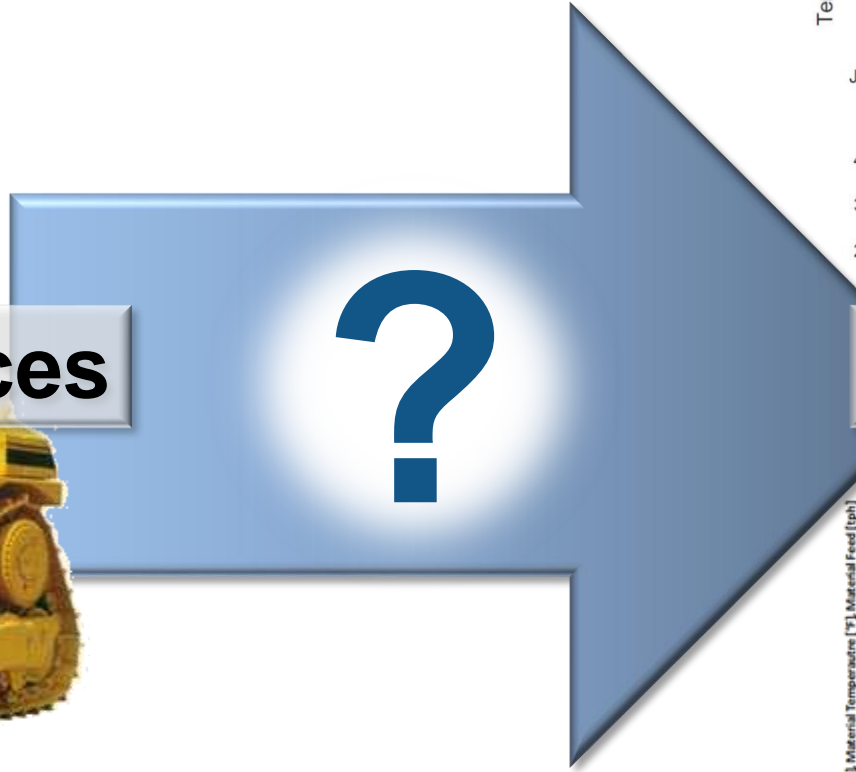


*“IoT is literally collecting **sensor data** from IP addressable sensors anywhere in the world for anything and transmitting the data.” [Tom Moore](#), IHS Analyst II, Industrial Automation*

The Goal of the IoT



Devices



Insight

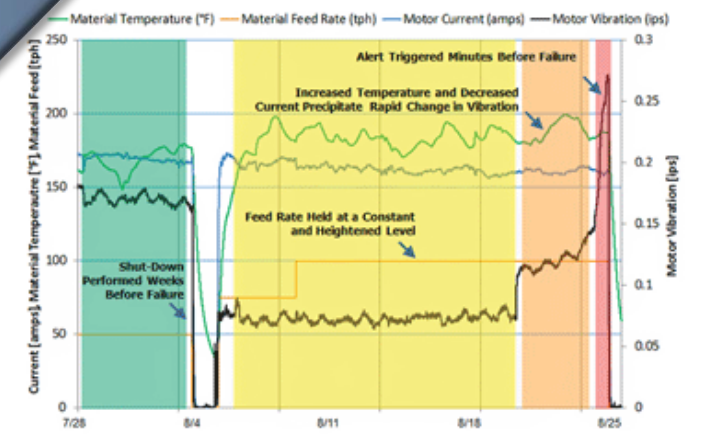


Figure 3. Vibration analysis: Data processed by the company's vibration analysis tool, and leading up to the fan's catastrophic failure, provides an ambiguous indication of the asset's degrading condition.

What is enabled by IoT sensor data?

Wearable /Healthcare



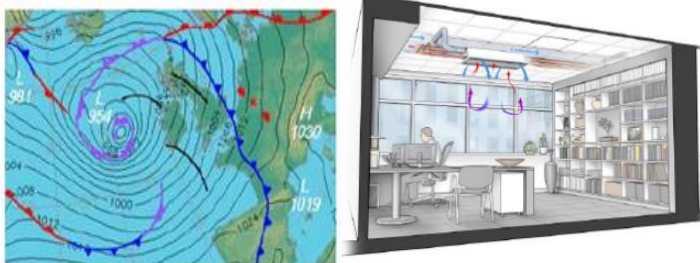
- Vital-sign monitor
- Home/Remote healthcare

Infra/Plant equipment



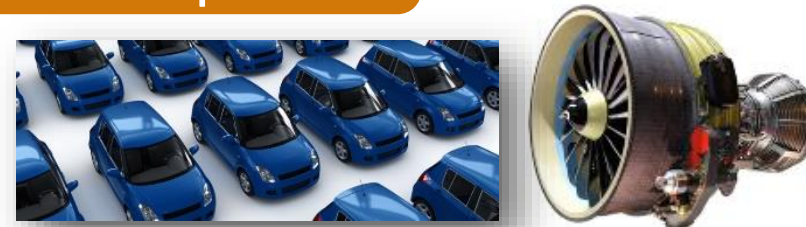
- Health monitoring
- Process monitoring

Weather Environment



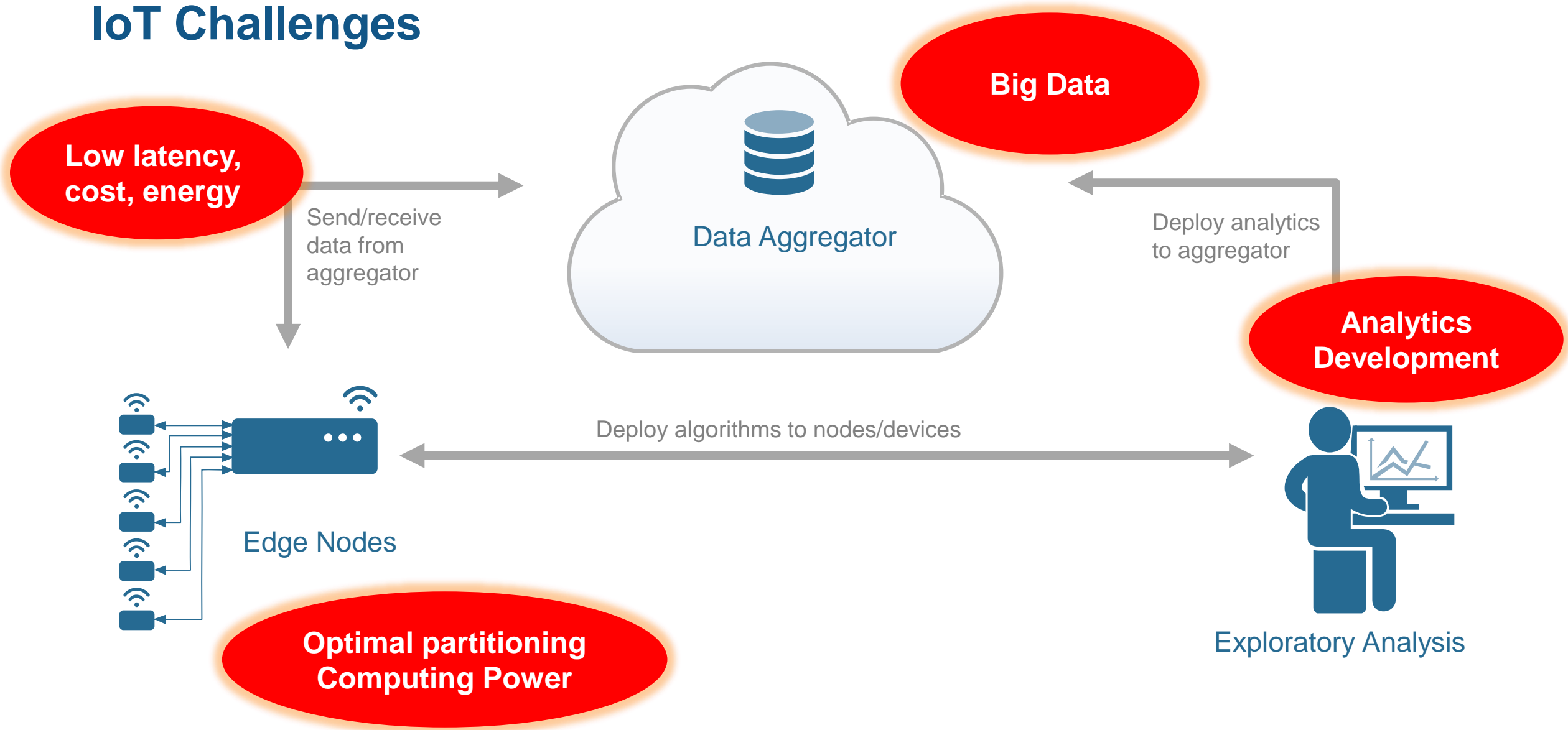
- Weather/ Power/disaster prediction
- Power demand forecast(EMS, Power trading)

Automotive Aerospace

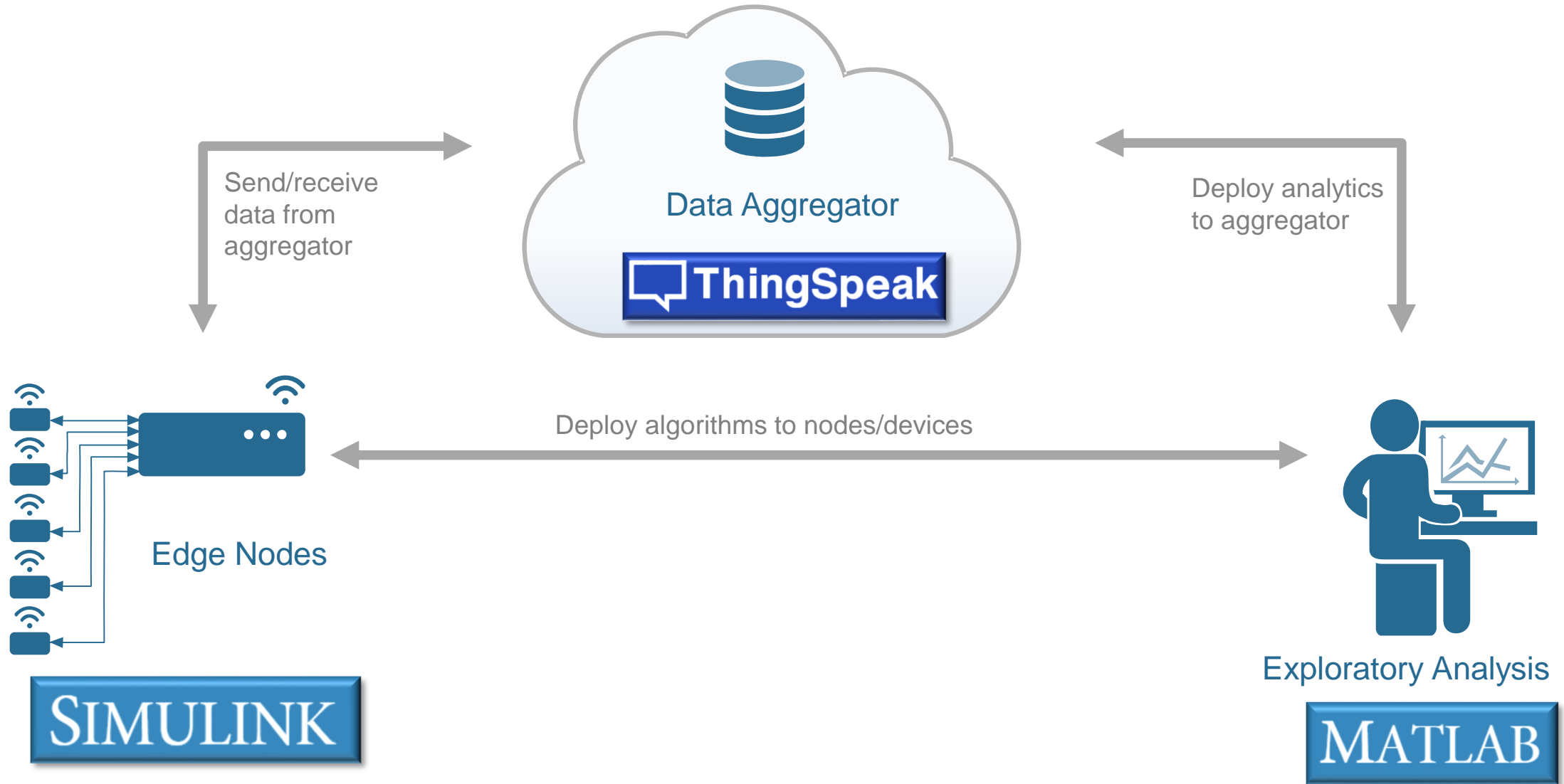


- Telematics, Health monitoring
- Safety driving, ADAS

IoT Challenges



MathWorks IoT Solutions



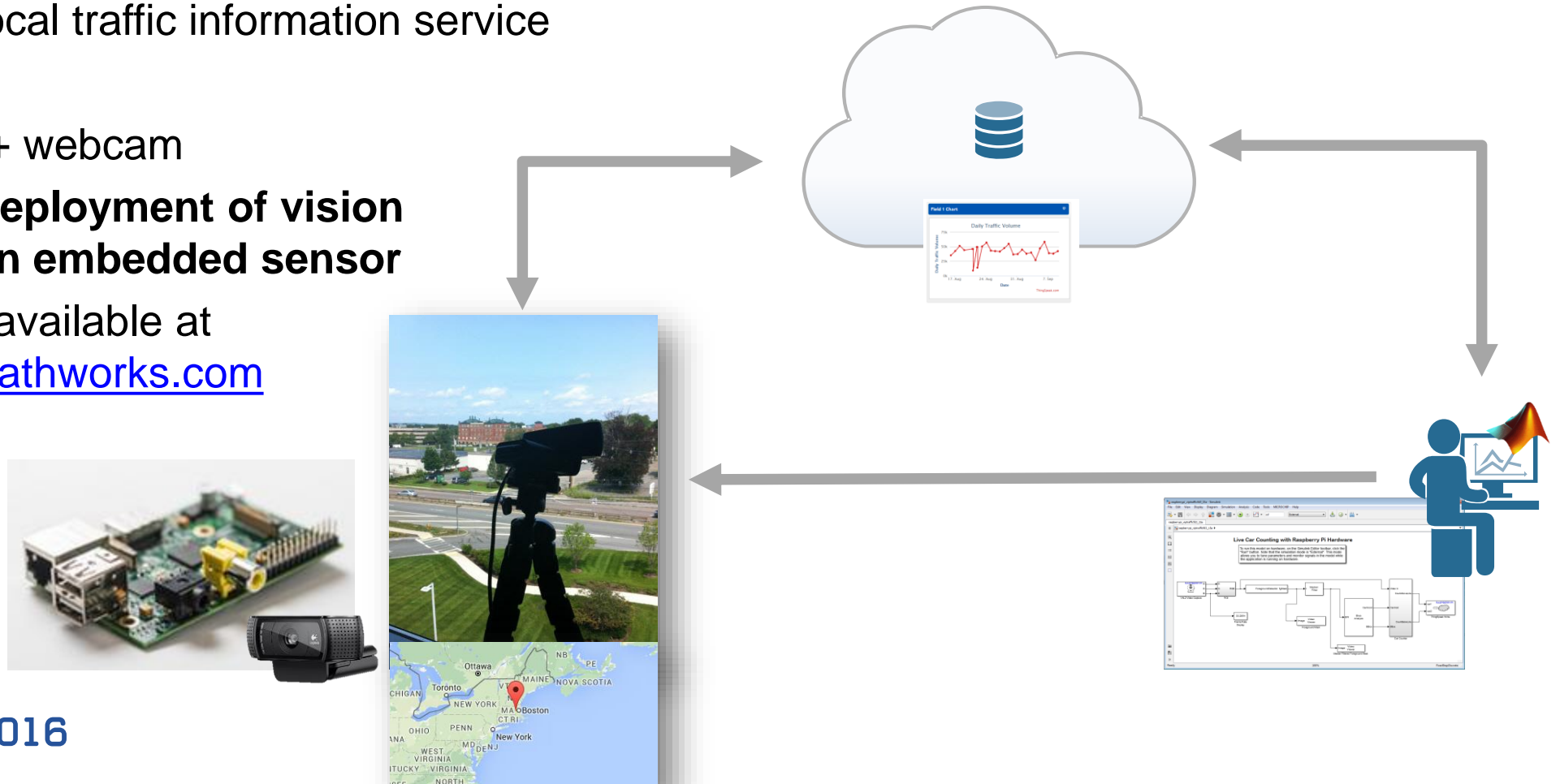
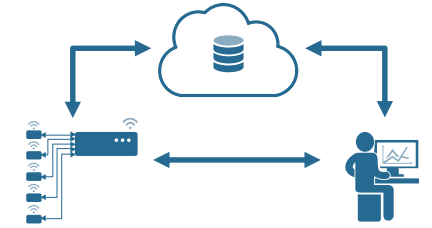
Example 1: Monitoring Traffic

Objectives

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

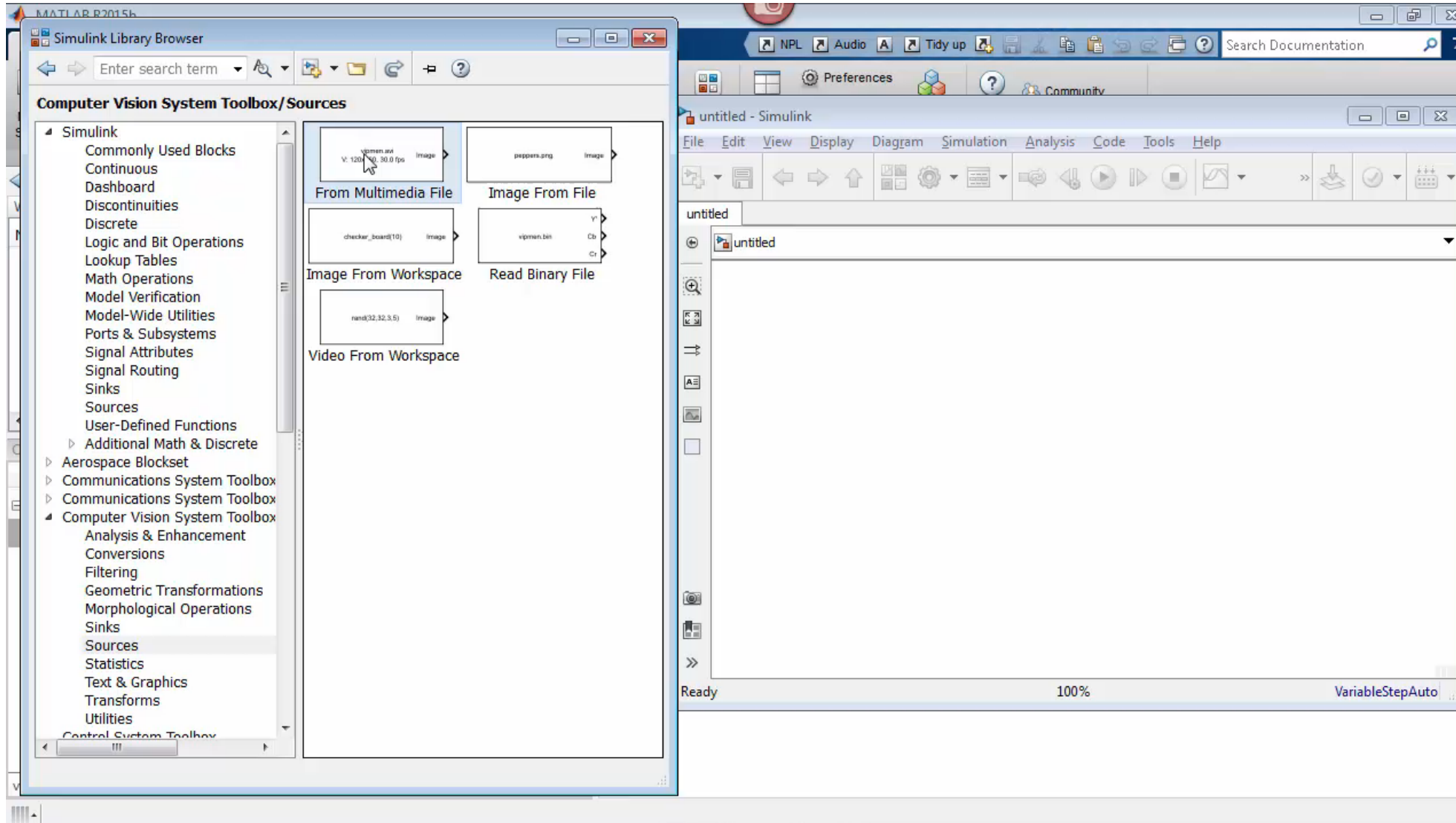
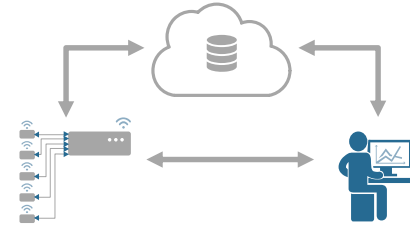
Solution

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



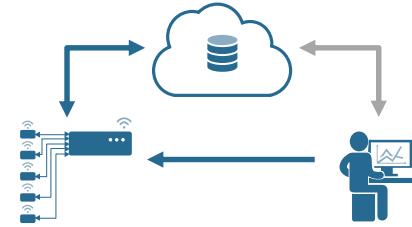
Traffic sensor – step 1

Design a car counter in Simulink



Traffic sensor – step 2

Port it to Raspberry Pi



MATLAB R2015b

HOME | PLOTS | APPS | SHORTCUTS

NPL | Audio | Tidy up | Search Documentation

FILE | VARIABLE | CODE | SIMULINK | ENVIRONMENT | RESOURCES

C:\> Docs > Material > MyEvents > 2015-10-07 - EXPO2015 > TrafficDemo > SensorDesign

Name	Value

Command Window

```
fx >>
```

Command History

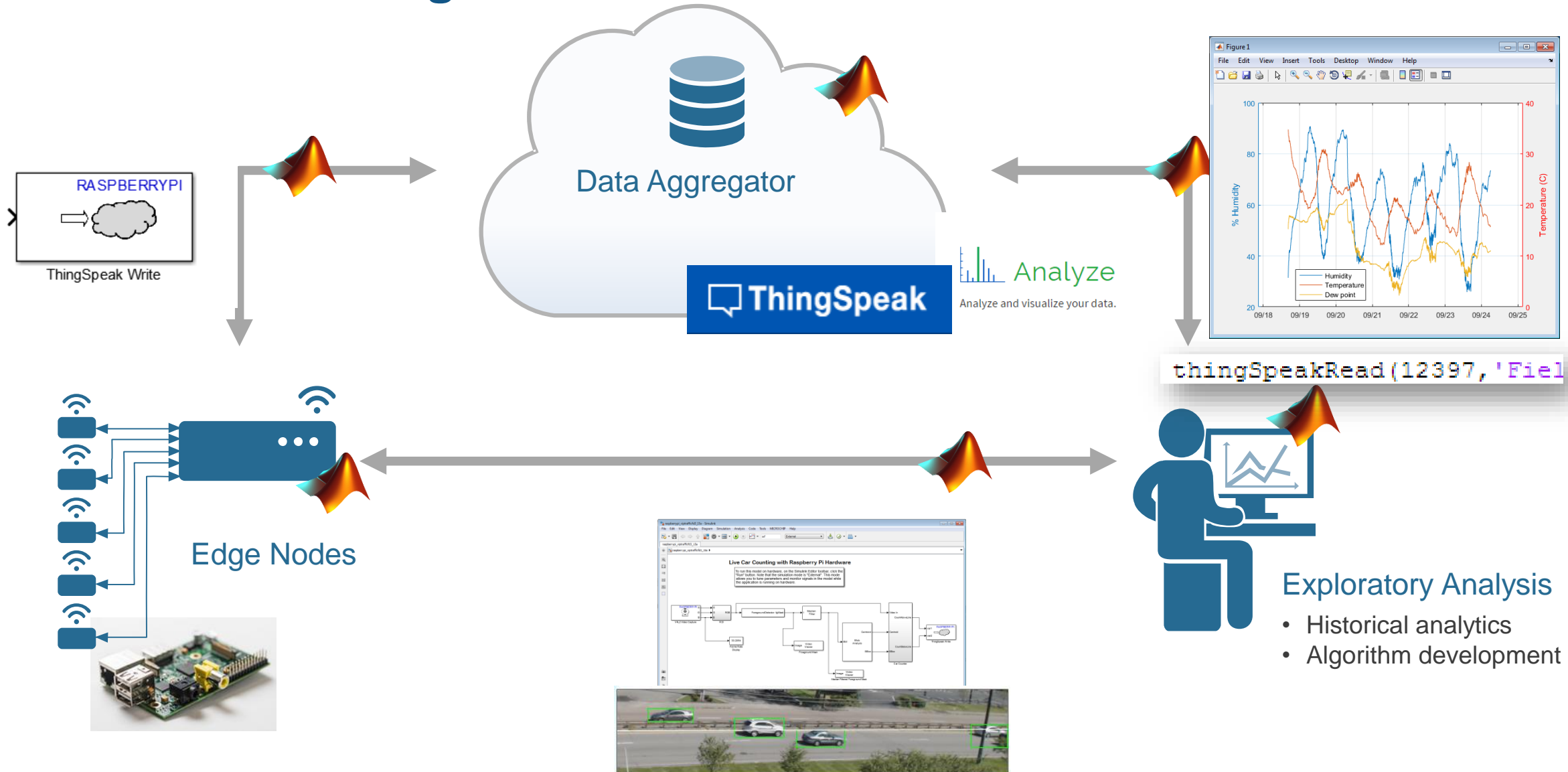
Name	Size	Date Modified

Current Folder

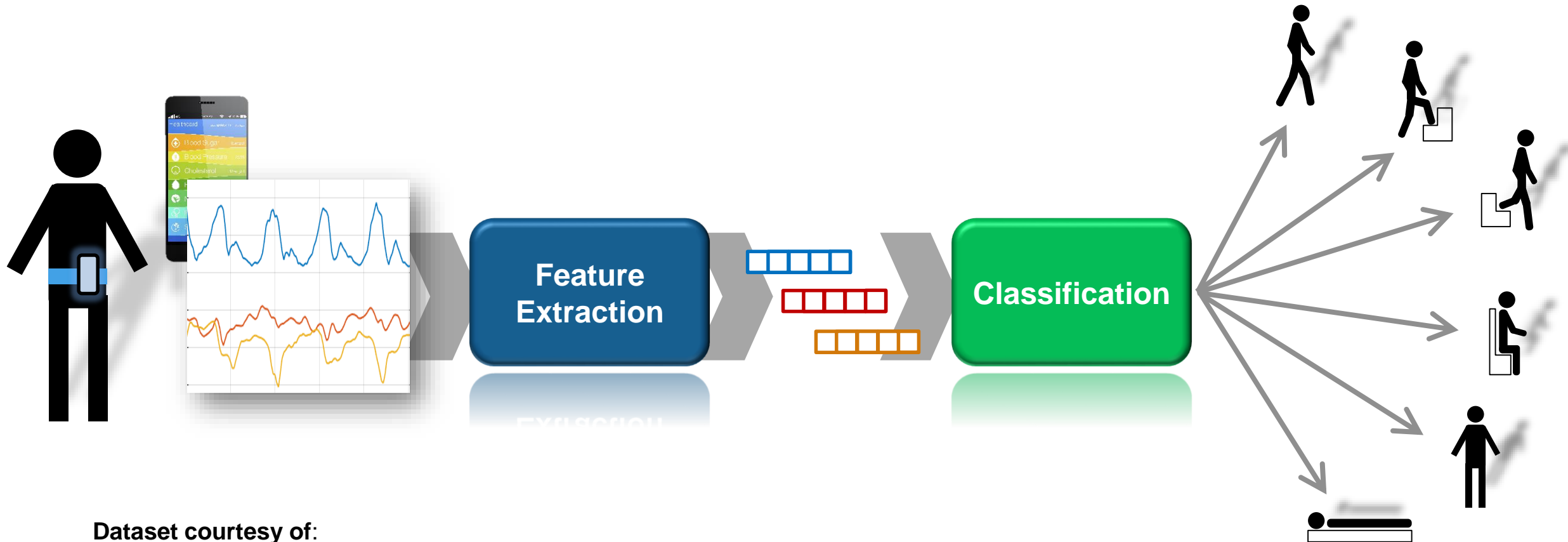
Details

Ready

IoT Traffic Monitoring Solution



Example 2: Human Activity Analysis and Classification



Dataset courtesy of:

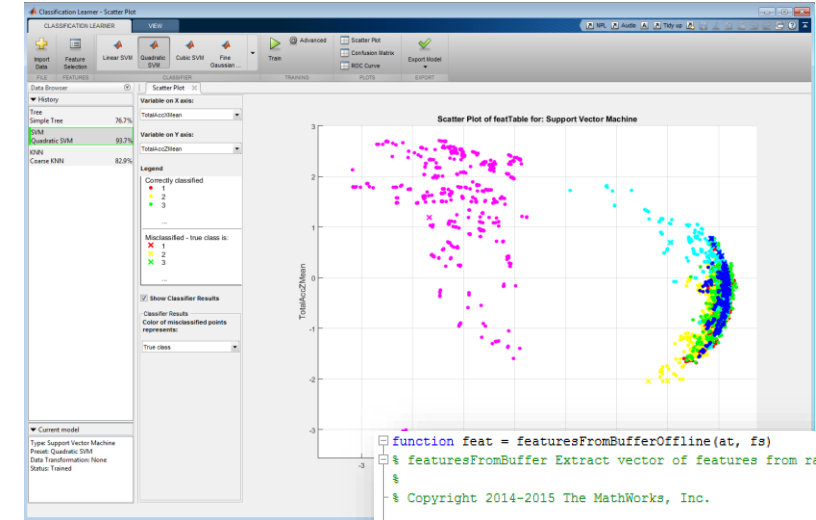
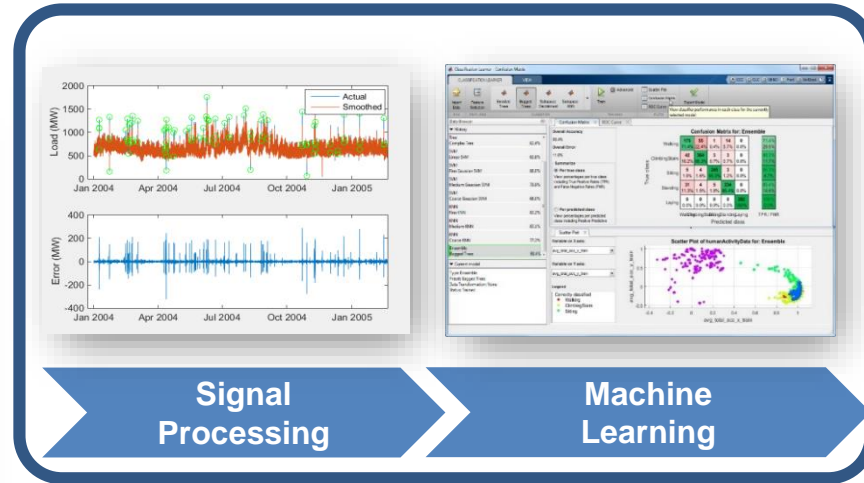
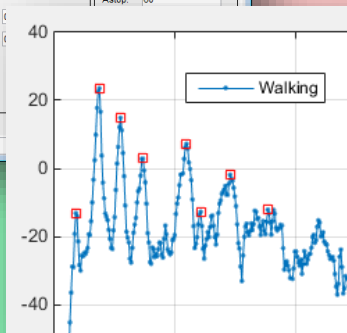
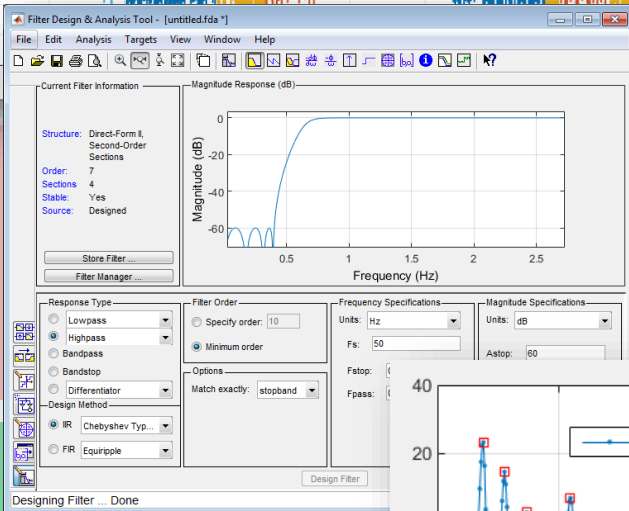
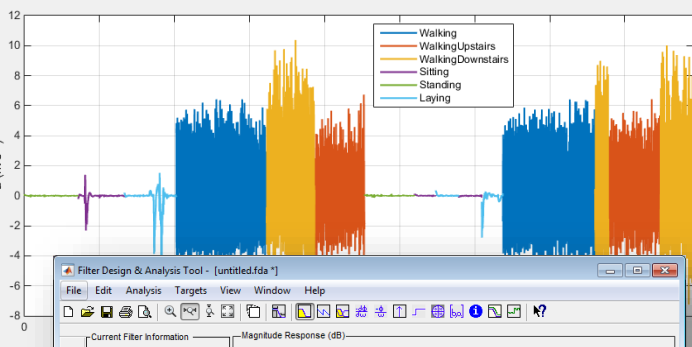
Davide Anguita, Alessandro Ghio, Luca Oneto, Xavier Parra and Jorge L. Reyes-Ortiz.

Human Activity Recognition on Smartphones using a Multiclass Hardware-Friendly Support Vector Machine.

International Workshop of Ambient Assisted Living (IWAAL 2012). Vitoria-Gasteiz, Spain. Dec 2012

<http://archive.ics.uci.edu/ml/datasets/Human+Activity+Recognition+Using+Smartphones>

Sensor Data Analytics Workflow – the bigger picture



```
function feat = featuresFromBufferOffline(at, fs)
% featuresFromBuffer Extract vector of features from raw
% Copyright 2014-2015 The MathWorks, Inc.

% Initialize feature vector
feat = zeros(1,66);

% Average value in signal buffer for all three accelera
feat(1:3) = mean(at,1);

% Initialize digital filter
fhp = hpfilter;

% Remove gravitational contributions with digital filter
ab = filter(fhp,at);

% RMS value in signal buffer for all three acceleration
feat(4:6) = rms(ab,1);

% Autocorrelation features for all three acceleration
% height of main peak; height and position of second pe
feat(7:15) = autocorrFeatures(ab, fs);

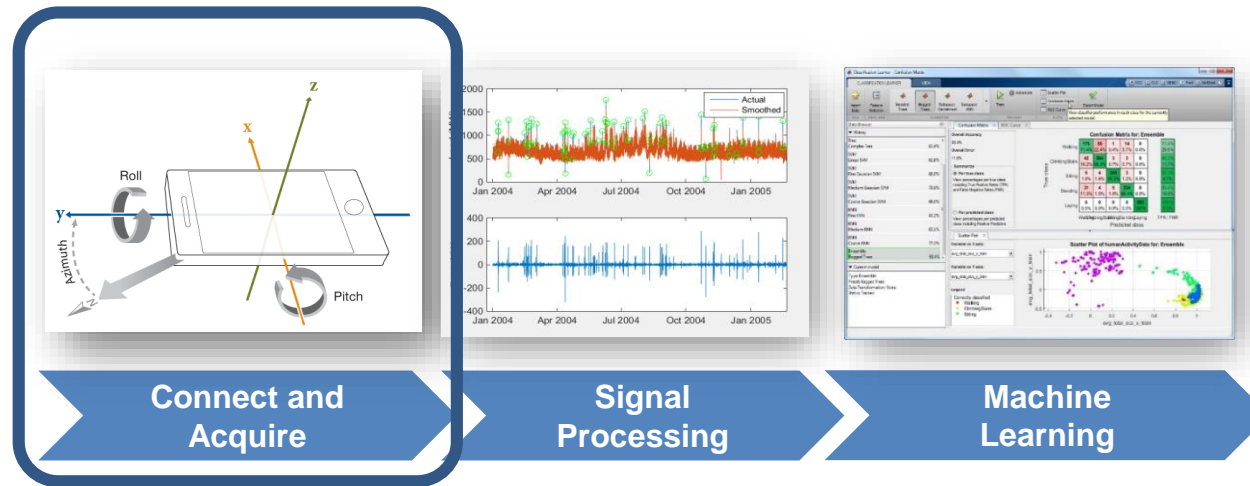
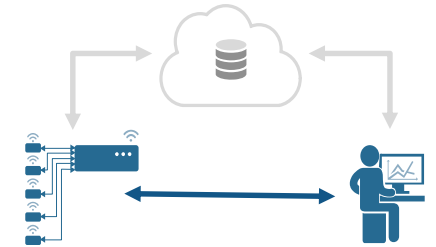
% Spectral peak features (12 each): height and position
feat(16:51) = spectralPeaksFeatures(ab, fs);

% Spectral power features (5 each): total power in 5 ad
% and pre-defined frequency bands
feat(52:66) = spectralPowerFeatures(ab, fs);

% --- Helper functions
function feats = autocorrFeatures(x, fs) ...
function feats = spectralPeaksFeatures(x, fs) ...
function feats = spectralPowerFeatures(x, fs) ...
```

- Domain knowledge
- Open-ended problem
- Long discovery cycles
- Built-in algorithms
- Concise code (54 lines for 66 features!)
- Apps and visualisation accelerate insight

Sensor Data Analytics Workflow – the bigger picture



- Different tools and environments
- Disconnect between hardware and analysis
- Inefficiencies in data sharing

- MATLAB Connects to DAQ interfaces and sensors directly. E.g.
 - [Android Sensor Support](#)
 - [iPhone and iPad Sensor Support](#)

Hardware Support

Overview Search Hardware Support Request Hardware Support

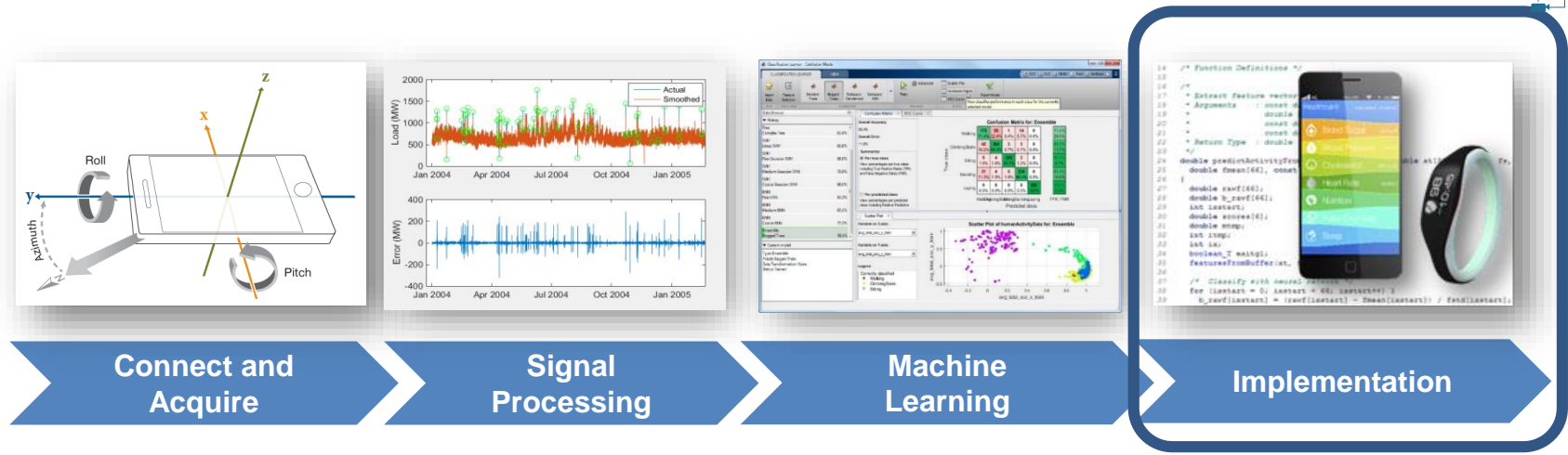
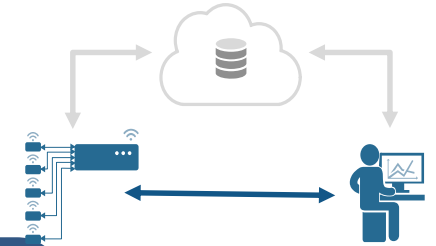
iPhone and iPad Sensor Support from MATLAB
 Use MATLAB to acquire accelerometer, magnetometer, gyroscope, in sensors on your iPhone or iPad.

- ▶ [Android Sensor Support from MATLAB](#)
- ▶ [iPhone and iPad Sensor Support from MATLAB](#)
- ▶ [Samsung GALAXY Android Support from Simulink](#)
- ▶ [iPhone and iPad Support from Simulink](#)
- ▶ [iPhone and iPad Support from MATLAB Coder](#)

MATLAB® supports the acquisition of data from the built-in sensors on Apple® iPhone™ and iPad™. With the MATLAB Support Package for Apple iOS Sensors, you can log data or query the most recent data



Sensor Data Analytics Workflow – the bigger picture



```

14 /* Function Definitions */
15
16 /*
17 * Extract feature vector
18 * Arguments : const double at[384]
19 *             double fs
20 *             const double fmean[66]
21 *             const double fstd[66]
22 * Return Type : double
23 */
24 double predictActivityFromSignalBuffer(const double at[384], double fs,
25 double fmean[66], const double fstd[66])
26 {
27     double rawF[66];
28     double b_rawF[66];
29     int ixstart;
30     double scores[6];
31     double mtmp;
32     int itmp;
33     int ix;
34     boolean_T exitg1;
35     featuresFromBuffer(at, fs, rawF);
36
37 /* Classify with neural network */
38 for (ixstart = 0; ixstart < 66; ixstart++) {
39     b_rawF[ixstart] = (rawF[ixstart] - fmean[ixstart]) / fstd[ixstart];

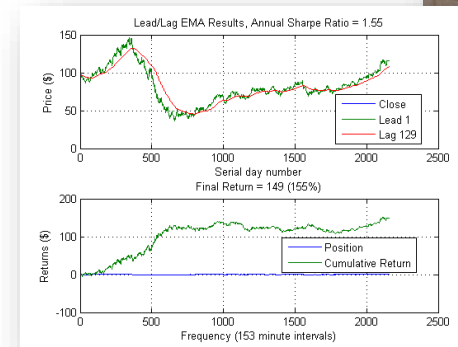
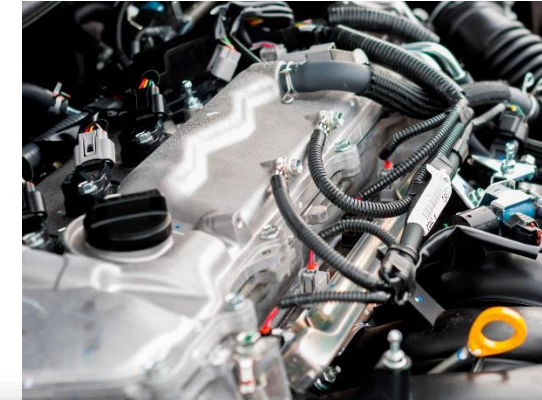
```

- Signal analysis vs. on-line DSP
- From Machine Learning theory to pre-trained, low-footprint classifiers
- MATLAB vs. C/C++
- Streaming algorithms, data sources and visualization for System modelling and simulation
- Automatic code generation

Signal analysis for classification

Application examples

- Mobile sensing
- Structural health monitoring (SHM)
- Fault and event detection
- Automated trading
- Radar post-processing
- Advanced surveillance
- ...



Customer Study: BuildingIQ

Predictive Energy Optimization

Opportunity

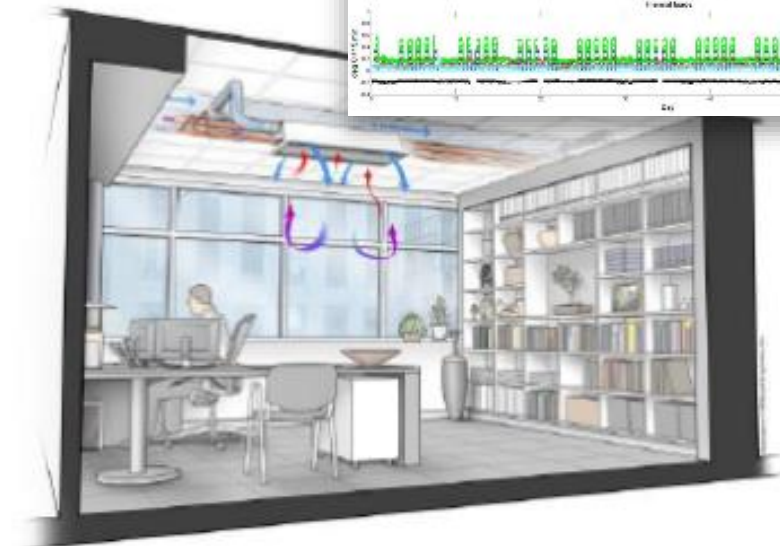
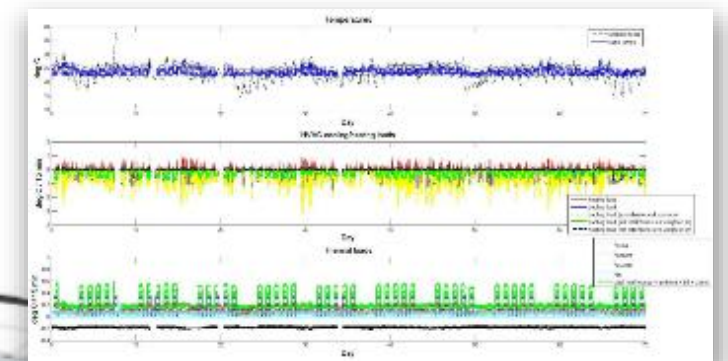
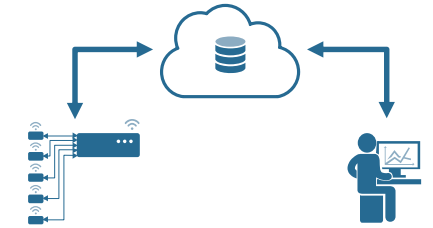
- **Real-time, cloud-based system** for commercial building owners to reduce energy consumption of HVAC operation

Analytics Use

- **Data:** 3 to 12 months of data from power meters, thermometers, and pressure sensors, as well as weather and energy cost, comprising billions of data points
- **Machine learning:** SVM regression, Gaussian mixture models, k-means clustering
- **Optimization:** multi-objective, constrained

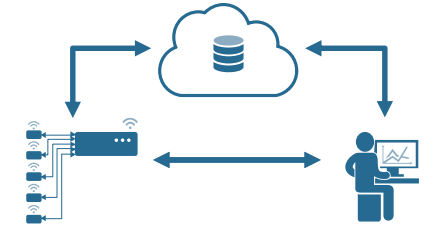
Benefit

- Typical energy consumption reduced 15-25%



Customer Study: iSonea

Cloud and Embedded Analytics



Opportunity

- Develop an acoustic respiratory monitoring system for wheeze detection and asthma management

Analytics in cloud and embedded

- Captures 30 seconds of windpipe sound and processes the data locally to clean up and reduce ambient noise
- Invokes spectral processing and pattern-detection analytics for wheeze detection on iSonea server in the cloud
- Provides feedback to the patient on their smartphone

Benefit

- Eliminates error-prone self-reporting and visits to the doctor

iSonea



Summary

- Develop Lightweight IoT systems entirely in MATLAB
- Integrate MATLAB algorithms within professional IoT systems

Q and A