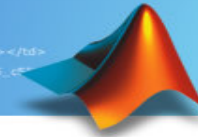


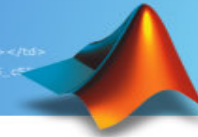
Design Challenges for Sensor Data Analytics in Internet of Things (IoT)

Phoebe Li, Terasoft Inc.

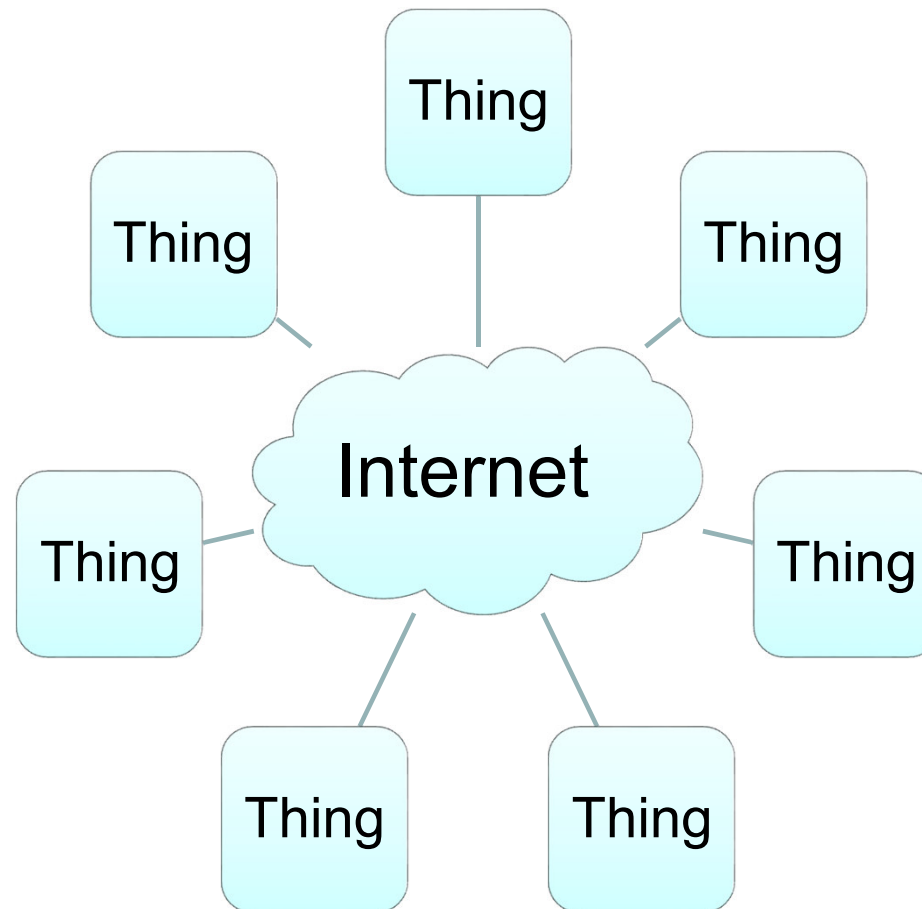


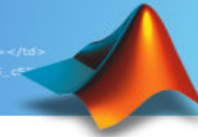
Agenda

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

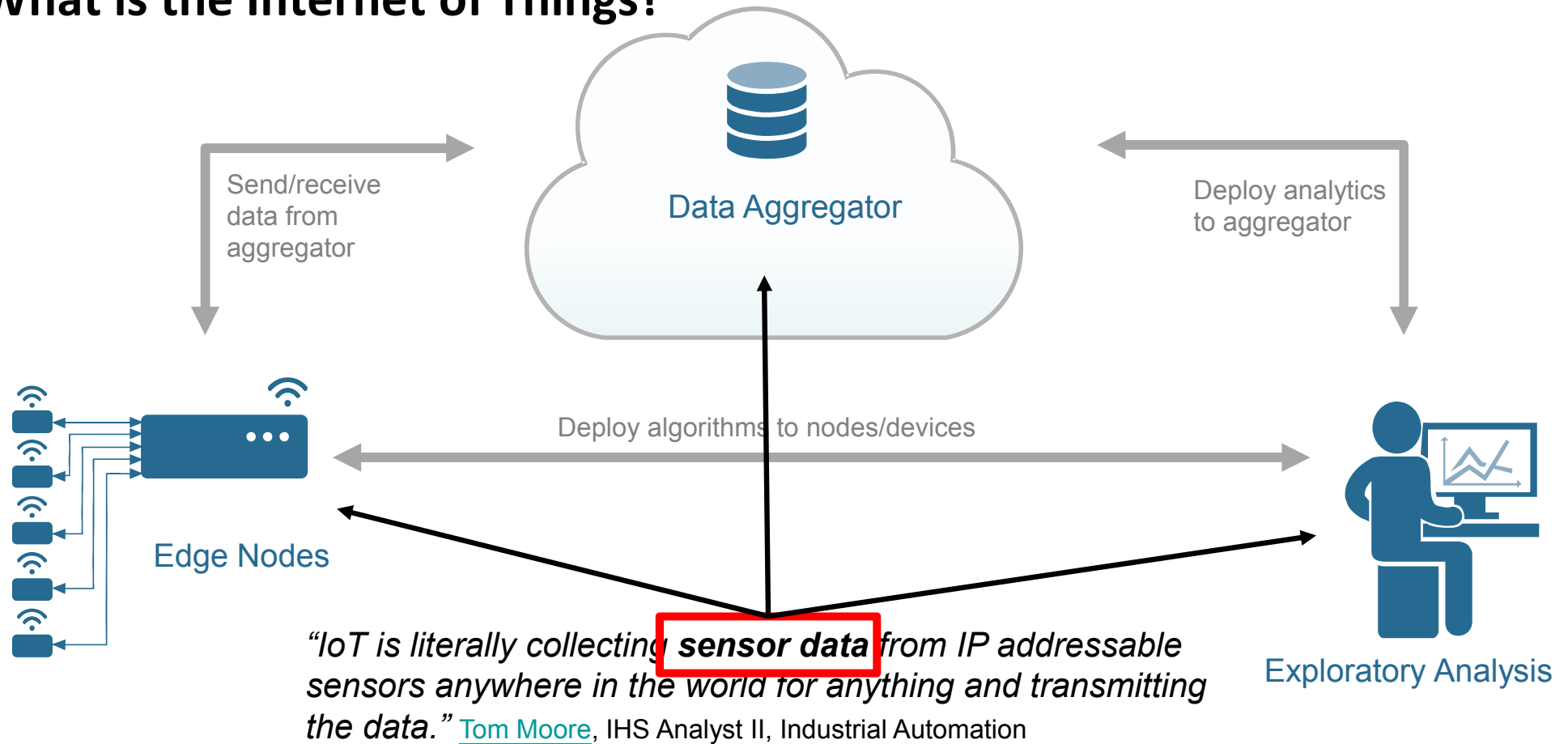


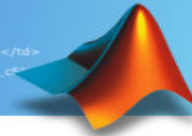
What is the Internet of Things?





What is the Internet of Things?



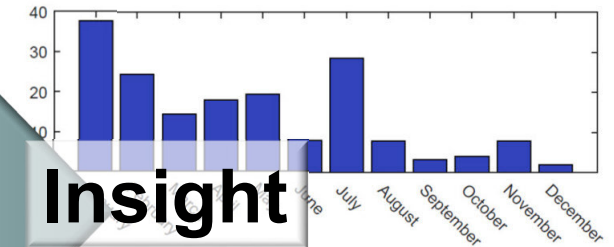
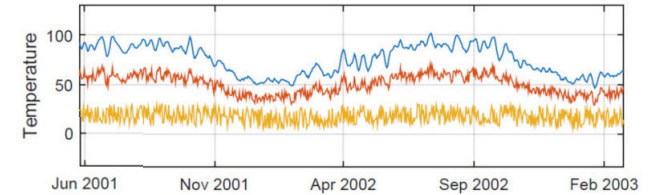


The Goal of the IoT



Devices

?



Insight

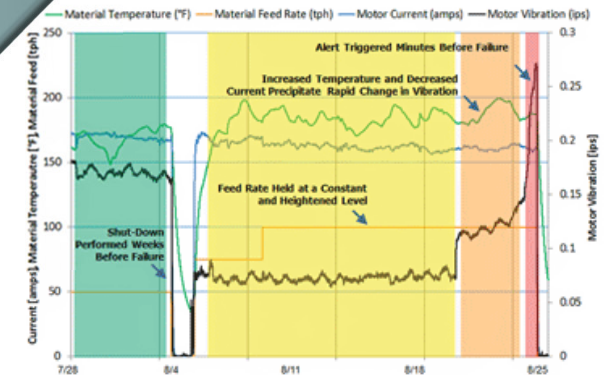
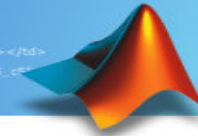


Figure 3. Vibration analysis: Data processed by the company's vibration analysis tool, and leading up to the fan's catastrophic failure, provides an ambiguous indication of the asset's degrading condition.



What is enabled by IoT sensor data?

Wearable /Healthcare



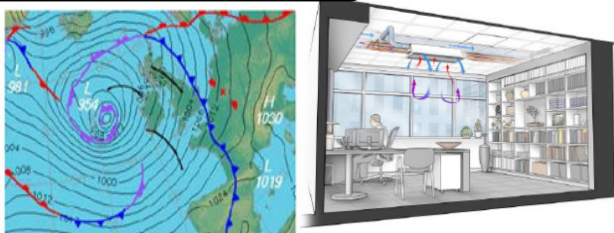
- Vital-sign monitor
- Home/Remote healthcare

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

Low latency,
cost, energy

Send/receive
data from
aggregator

Data Aggregator

Big Data

Deploy analytics
to aggregator

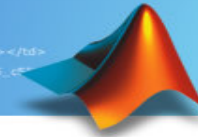
Analytics
Development

Deploy algorithms to nodes/devices

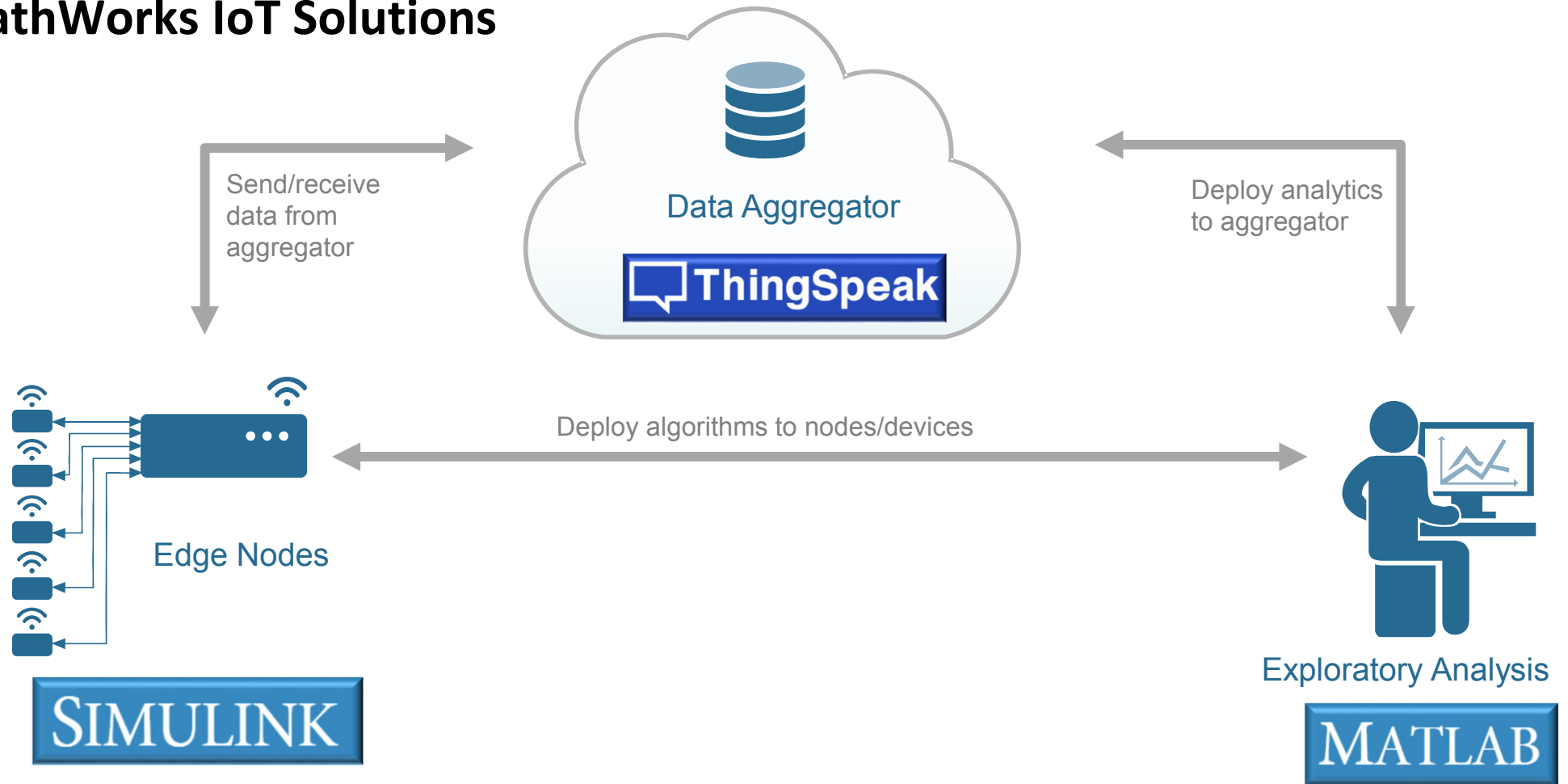
Edge Nodes

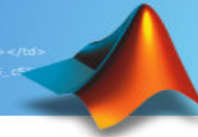
Optimal partitioning
Computing Power

Exploratory Analysis



MathWorks IoT Solutions





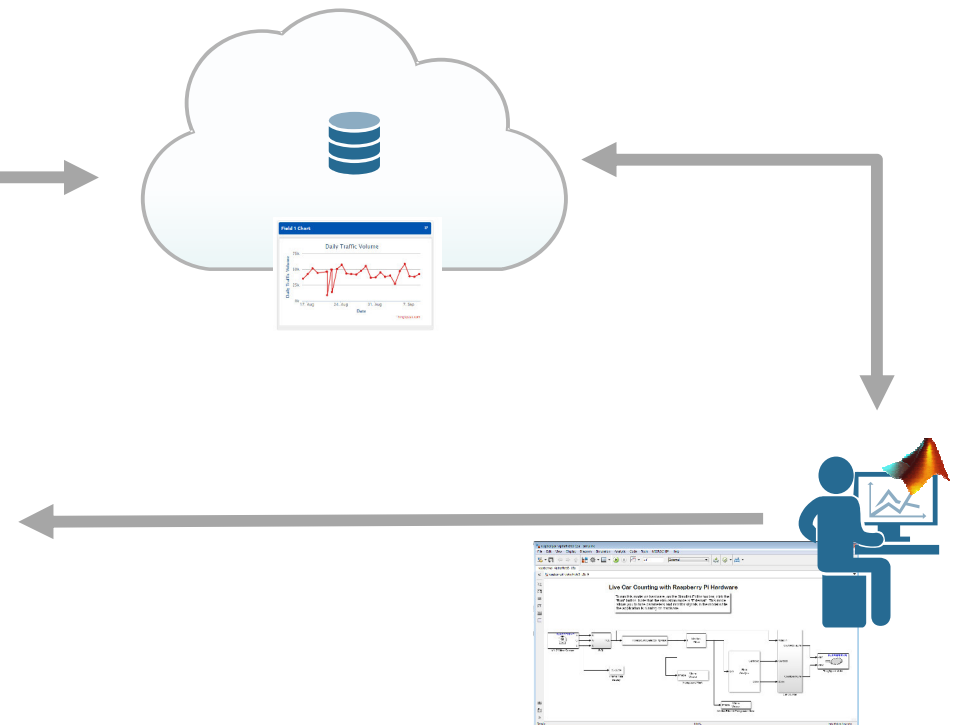
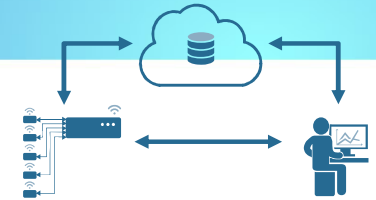
Example 1: Monitoring Traffic

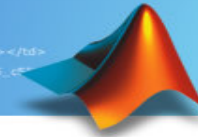
Objectives

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

Solution

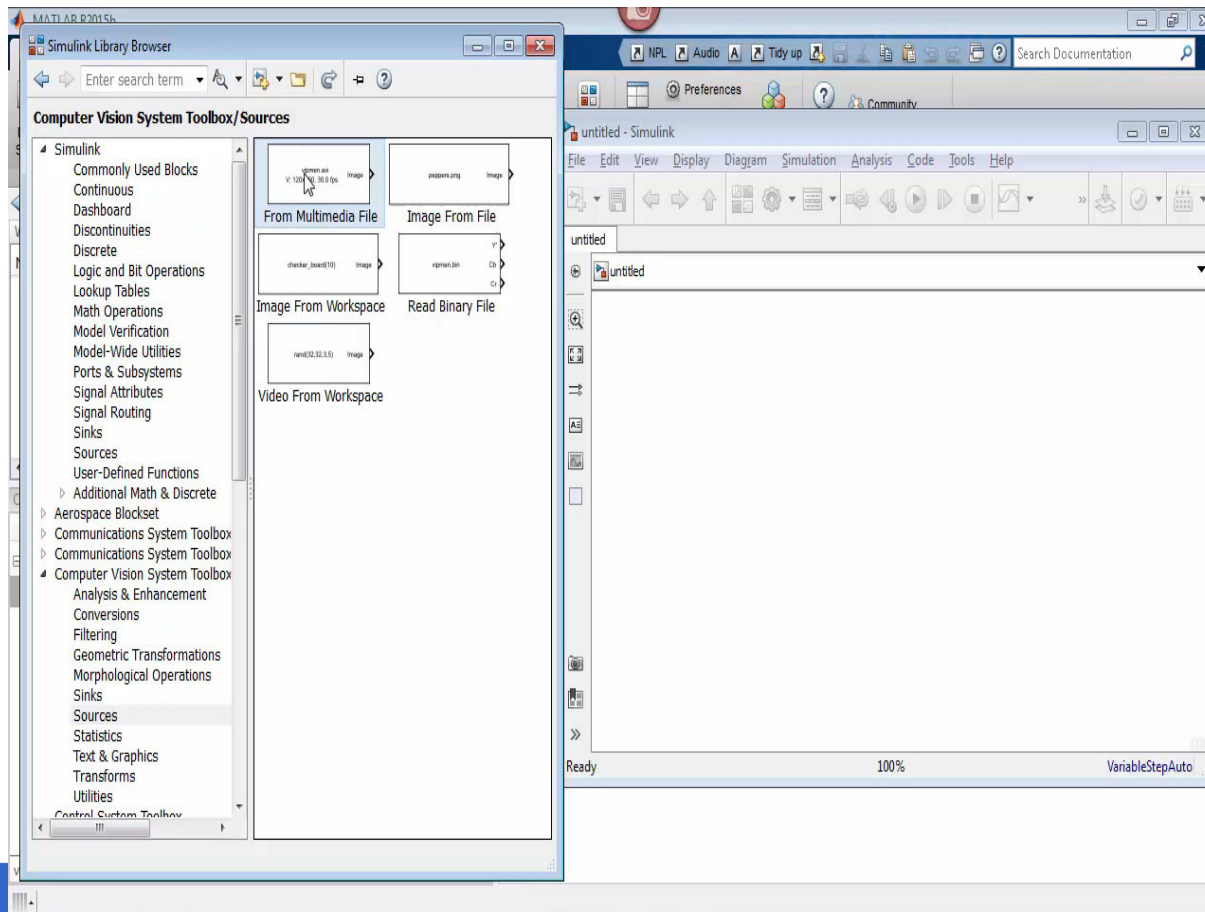
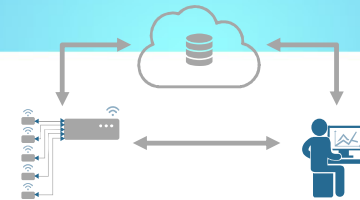
- RaspberryPi + webcam
- Automated deployment of vision algorithms on embedded sensor**
- Full example available at makerzone.mathworks.com

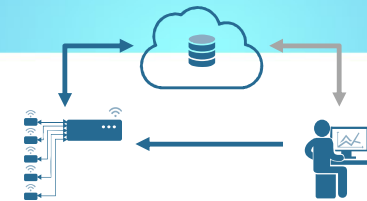
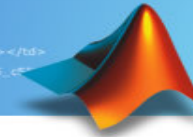




Traffic sensor – step 1

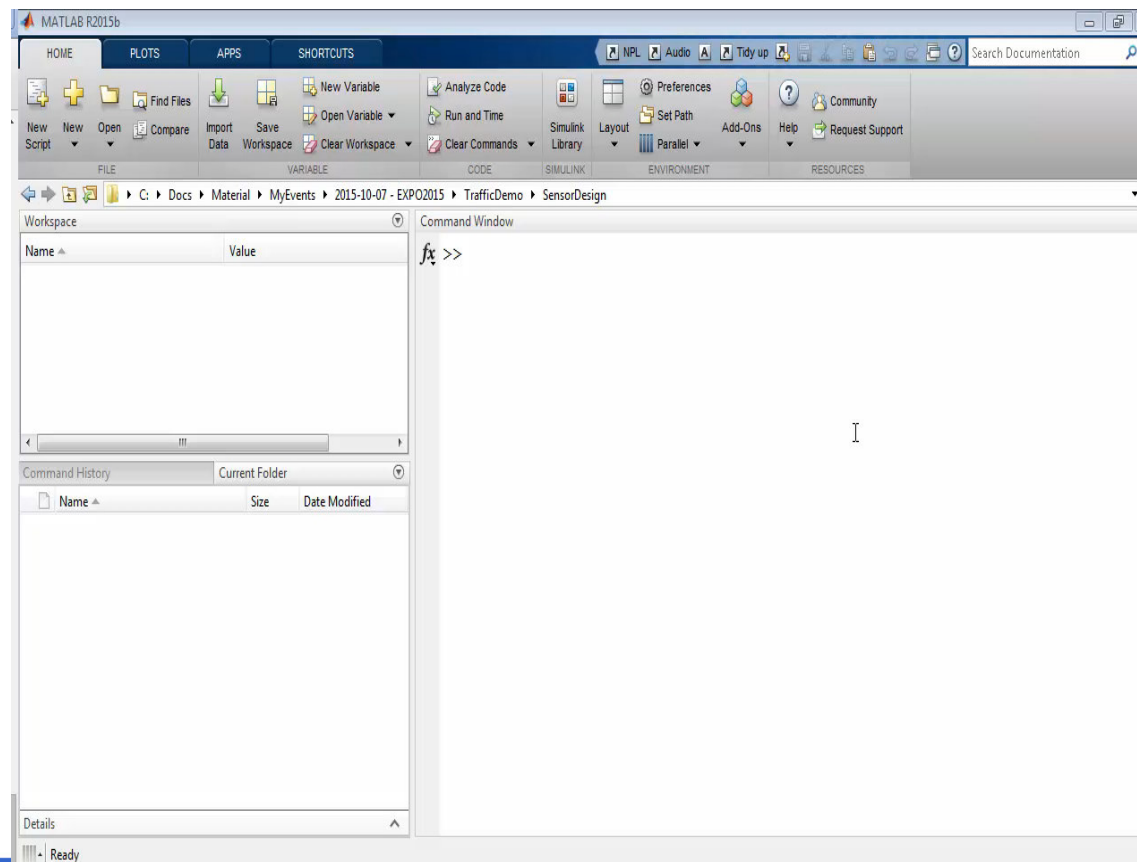
Design a car counter in Simulink



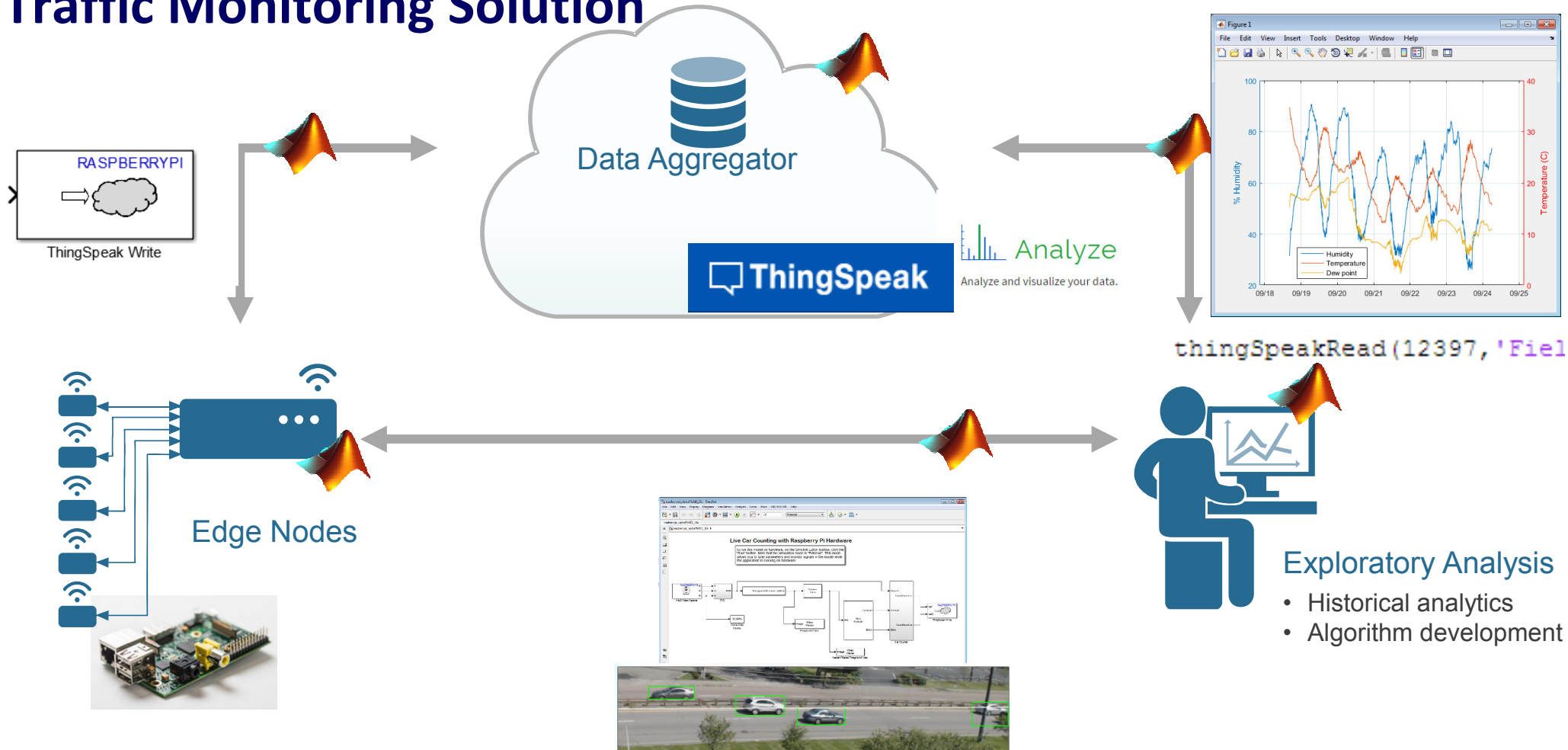


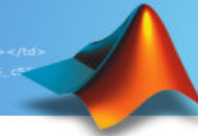
Traffic sensor – step 2

Port it to Raspberry Pi

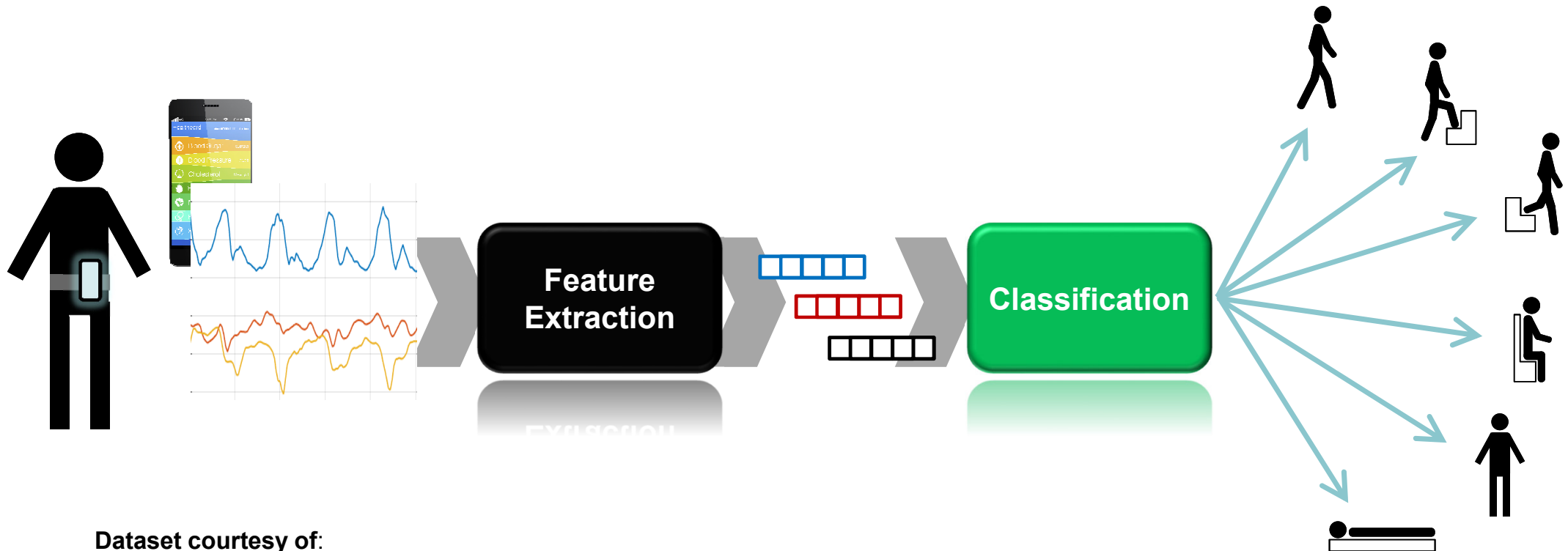


IoT Traffic Monitoring Solution





Example 2: Human Activity Analysis and Classification



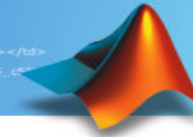
Dataset courtesy of:

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

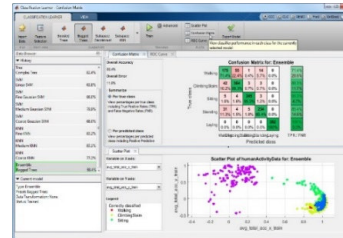
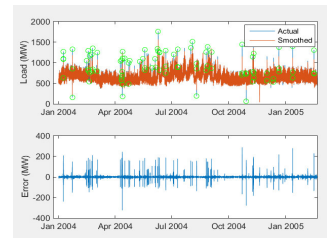
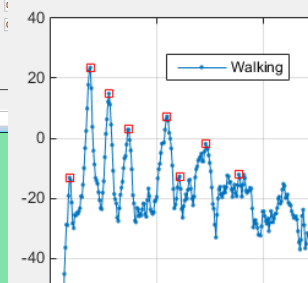
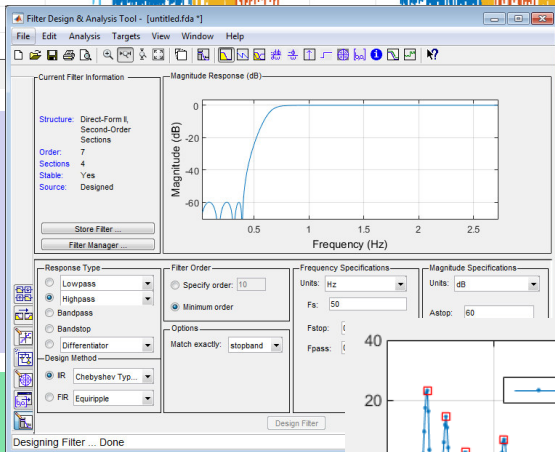
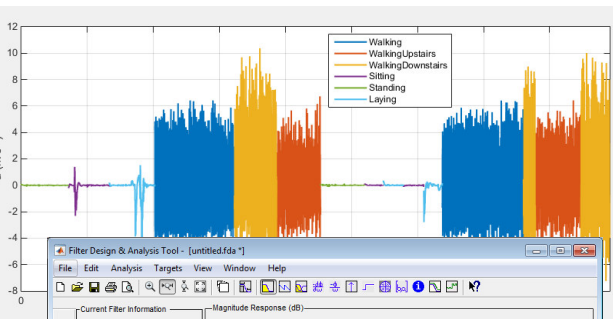
Human Activity Recognition on Smartphones using a Multiclass Hardware-Friendly Support Vector Machine.

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

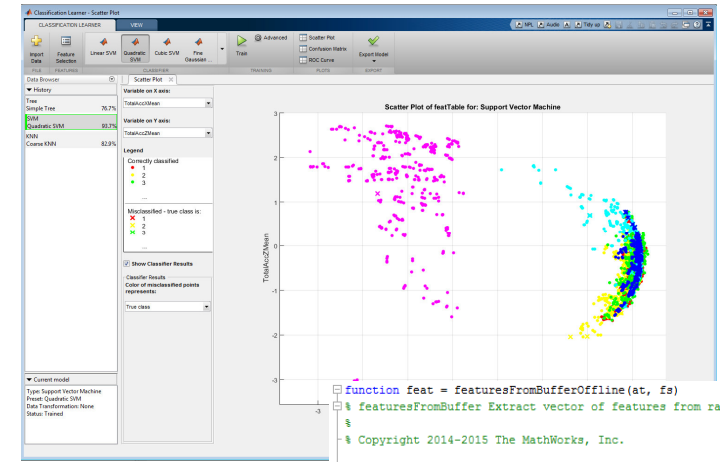
<http://archive.ics.uci.edu/ml/datasets/Human+Activity+Recognition+Using+Smartphones>



Sensor Data Analytics Workflow – the bigger picture



Signal Processing → Machine Learning



```
function feat = featuresFromBufferOffline(at, fs)
% featuresFromBuffer Extract vector of features from ra
%
% 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);

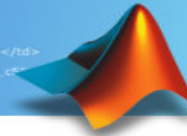
% Autocorrelation features for all three acceleration c
% height of main peak; height and position of second pe
feat(7:15) = autocorrFeatures(ab, fs);

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

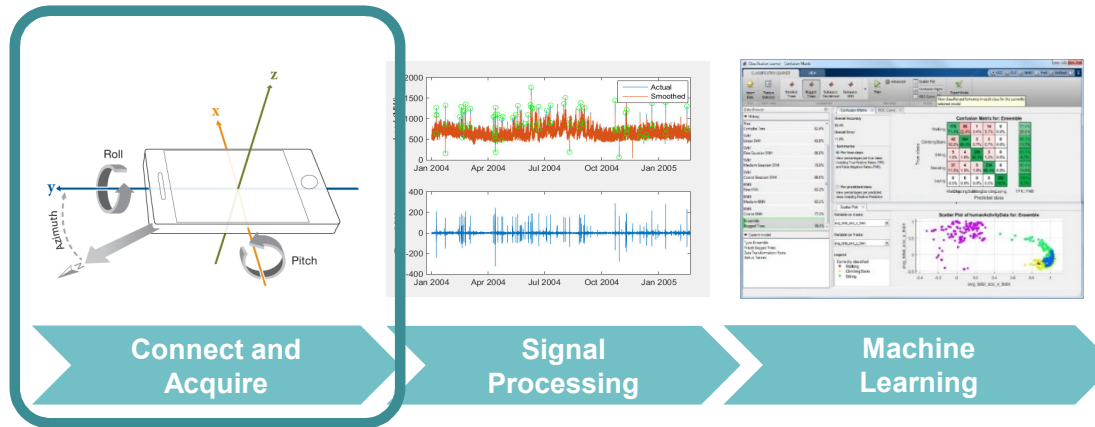
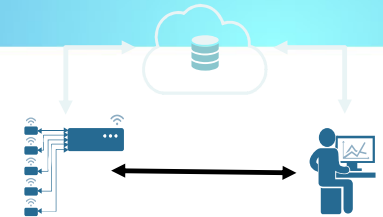
% Spectral power features (5 each): total power in 5 ad
% and pre-defined frequency bands
feat(52:66) = spectralPowerFeatures(ab, fs);

% --- 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

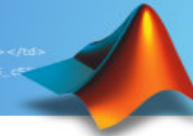
Overview Search Hardware Support Request Hardware Support

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

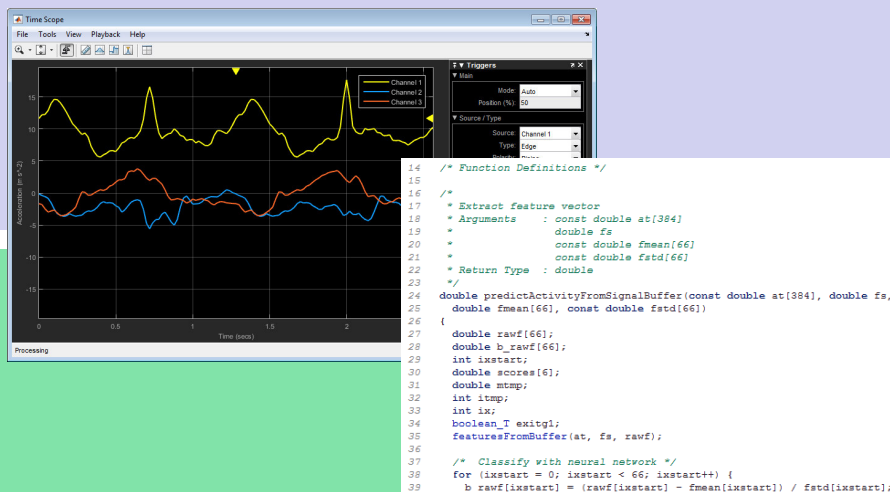
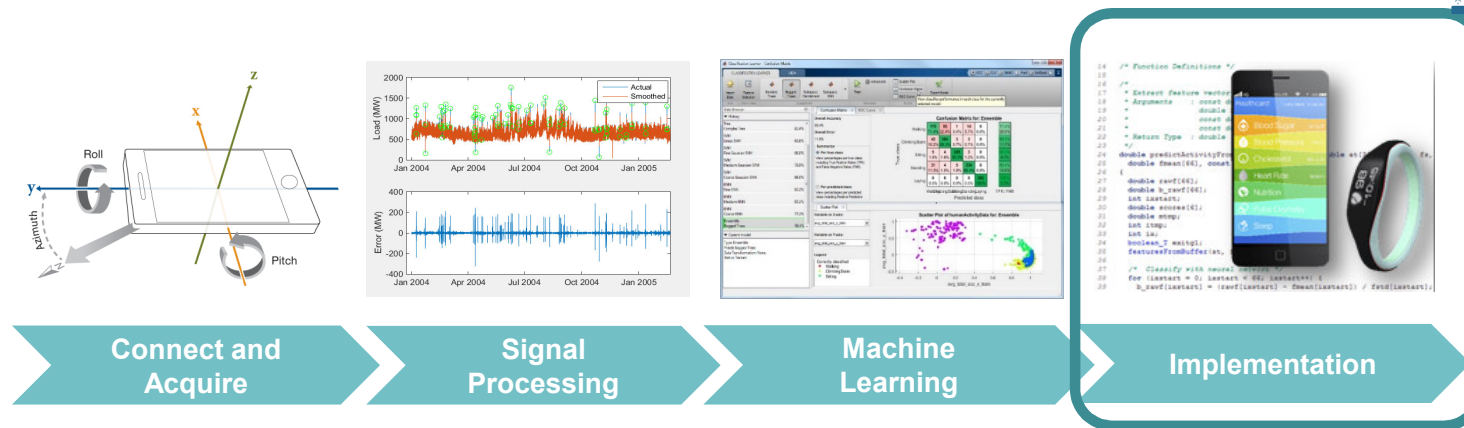
- ▶ [Android Sensor Support from MATLAB](#)
- ▶ [iPhone and iPad Sensor Support from MATLAB](#)
- ▶ [Samsung GALAXY Android Support from Simulink](#)
- ▶ [iPhone and iPad Support from Simulink](#)
- ▶ [iPhone and iPad Support from MATLAB Coder](#)

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

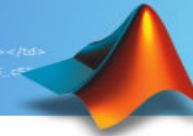




Sensor Data Analytics Workflow – the bigger picture



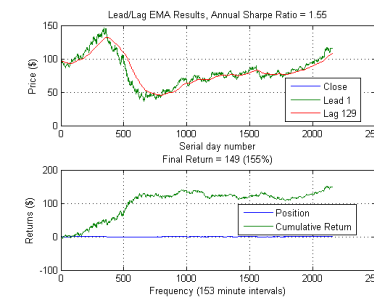
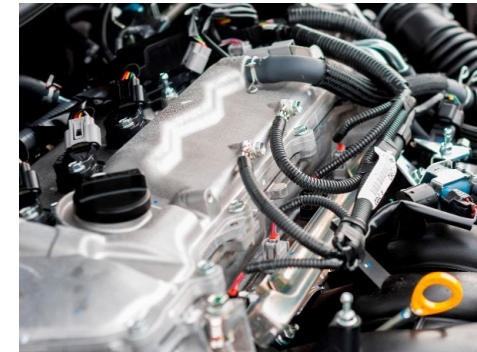
- Signal analysis vs. on-line DSP
- From Machine Learning theory to pre-trained, low-footprint classifiers
- MATLAB vs. C/C++
- Streaming algorithms, data sources and visualization for System modelling and simulation
- Automatic code generation

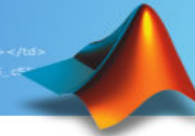


Signal analysis for classification

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

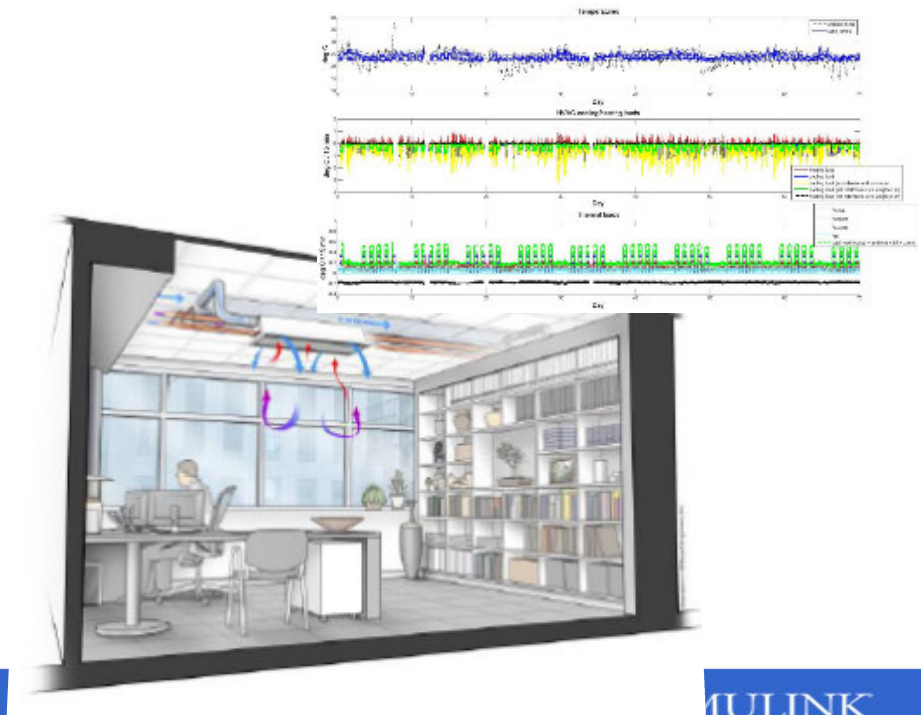
- **Real-time, cloud-based system** for commercial building owners to reduce energy consumption of HVAC operation

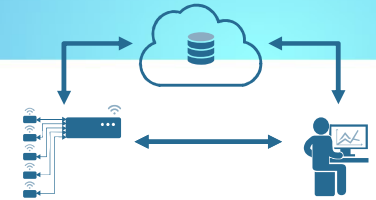
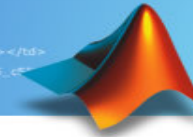
Analytics Use

- **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

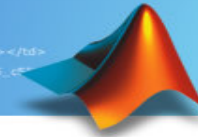
- Captures 30 seconds of windpipe sound and processes the data locally to clean up and reduce ambient noise
- Invokes spectral processing and pattern-detection analytics for wheeze detection on iSonea server in the cloud
- Provides feedback to the patient on their smartphone

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