

### IoT Technology Development Using MATLAB

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### Agenda

- 1. Accessing and aggregating data from edge nodes for algorithm development
- 2. Developing online analytics and monitoring of smart devices using ThingSpeak

(MathWorks IoT Platform)

- 3. Performing historical data analysis
- 4. Deploying analytics to embedded devices to enable smart edge nodes
- 5. Q&A

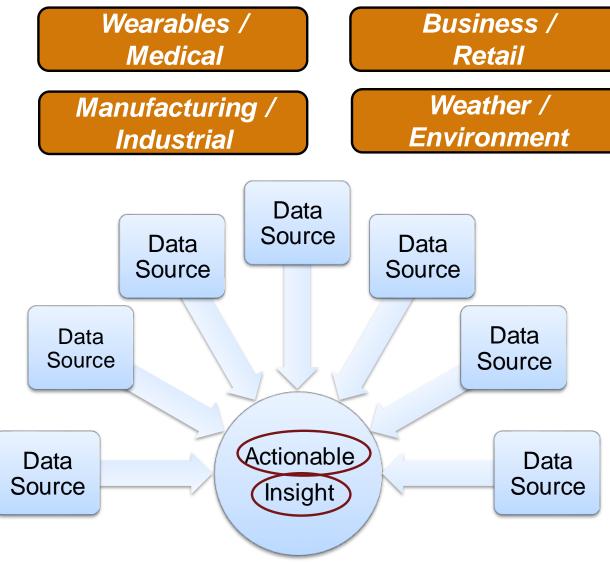


## What is IoT?



## Improve Business and Technology Through Intelligent Analysis of Data

- Data is being logged everywhere
- Data comes from many disparate sources
- Get insight from aggregated data and make actionable decisions to
  - Reduce costs and risks
  - Improve performance
  - Save lives





# **BuildingIQ Develops Proactive Algorithms for HVAC Energy Optimization in Large-Scale Buildings**

#### Challenge

Develop a real-time system to minimize HVAC energy costs in large-scale commercial buildings via proactive, predictive optimization

#### **Solution**

Use MATLAB to analyze and visualize big data sets, implement advanced optimization algorithms, and run the algorithms in a production cloud environment

#### Results

- Gigabytes of data analyzed and visualized
- Algorithm development speed increased tenfold
- Best algorithmic approaches quickly identified



Large-scale commercial buildings can reduce energy costs by 10–25% with BuildinglQ's energy optimization system.

"MATLAB has helped accelerate our R&D and deployment with its robust numerical algorithms, extensive visualization and analytics tools, reliable optimization routines, support for object-oriented programming, and ability to run in the cloud with our production Java applications."

Borislav Savkovic BuildingIQ



**Example – BuildingIQ Cloud Based Solution : Adaptive Building Energy** 

Management Building Time of Use Weather **Energy Prices** Managed Services & NOC Price Forecast Signals Demand **Open Access Platform** Response **Running Client Software** Optimal Price Control Secure **Optimization** Strategy Servers Program Current Tenant Building Comfort Condition Comfort



### **BuildingIQ**

#### **Adaptive building energy management**

#### **Application**

 Real-time, cloud-based system: predictive energy optimization (PEO) for commercial building owners to reduce energy consumption of HVAC operation by 15-25%

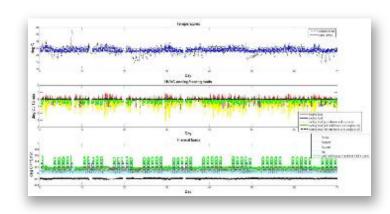
#### **Exploratory Analysis and Development**

- Algorithms developed 10 times faster than in JAVA
- 3 to 12 months of data from meters, sensors, weather, energy costs → billions of data points
- Machine Learning: SVM regression, Gaussian mixture models, k-means clustering

#### **Deployed Cloud Analytics**

- Periodic multi-objective optimizations using PEO models
- 10 25% savings on \$1M+ energy bills



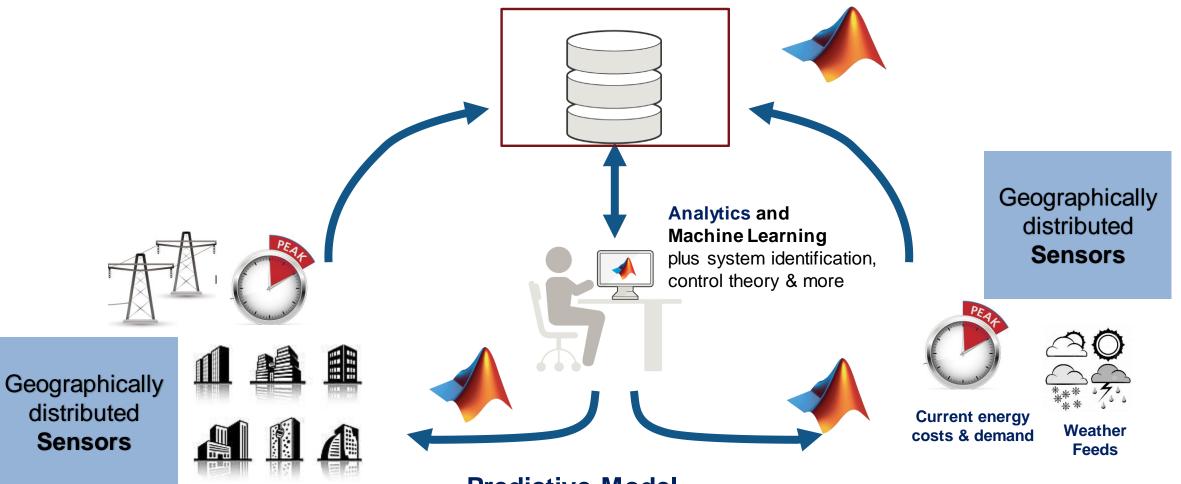


We could rapidly translate our prototypes into production algorithms that deal reliably with real-world noise and uncertainty

Borislav Savkovic, BuildinglQ



### How BuildingIQ used MATLAB to develop IoT System?

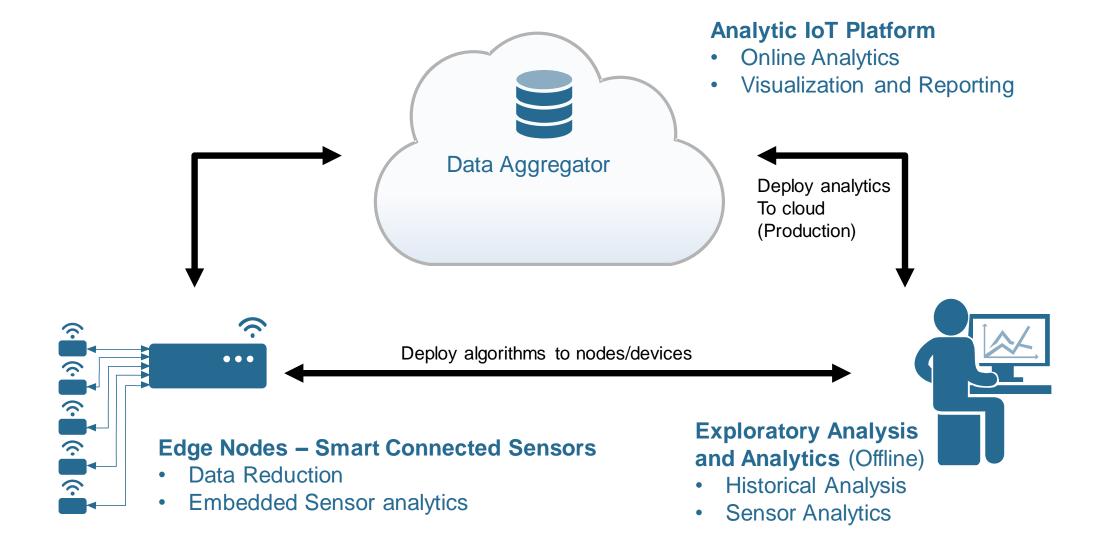


**Predictive Model** 

deployed on cloud with client system and real-time data feeds



### High Level Architectural View of IoT





### Challenges

**Analytics that increasingly** require both business and engineering data

**Multi-Disciplinary** Workflow

**Expertise in development of** custom web softwares or servers

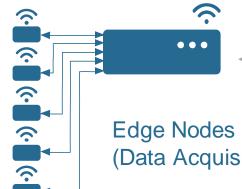
Deploying applications that run on

both traditional IT and embedded platforms

Data Aggregator

- Online Analytics
- **Data Visualization**

Deploy analytics to server (Production)



Deploy algorithms to nodes/devices

Edge Nodes (Data Acquisition)

**Exploratory Analysis** and Analytics (Development)

**Analytics that require** scalable computation



**Enable Domain Experts to be Data Scientists** 



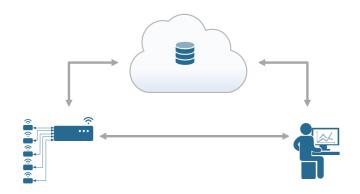
### Examples

1. Monitoring Weather



2. Monitoring Traffic





### **Example 1: Monitoring Weather**

#### **Objectives**

Measure, explore, discover weather patterns

Provide niche weather service

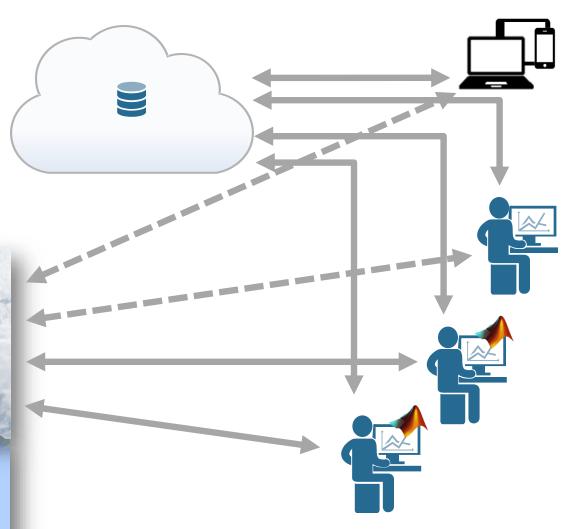
#### **Solution**

Arduino station with weather sensors

Cloud-based aggregation and analysis

 Full example available at makerzone.mathworks.com

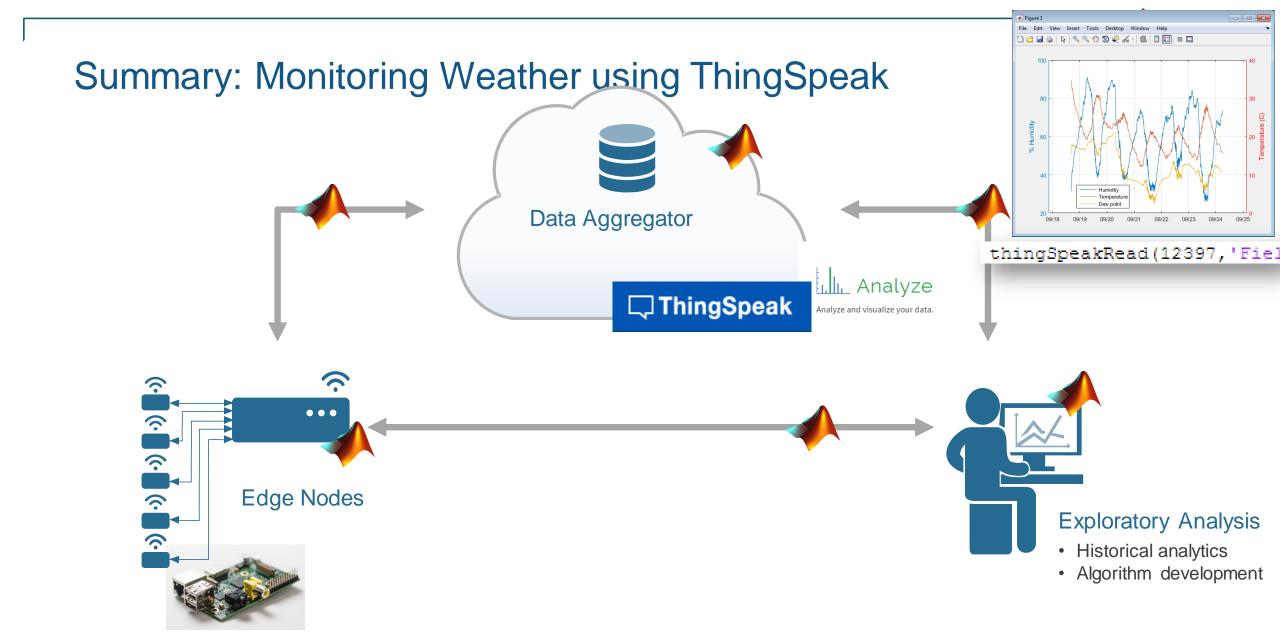




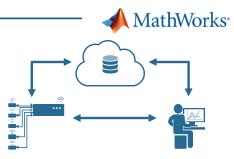
MathWorks<sup>®</sup>



Let's go to ThingSpeak . . .



### Example 2: Building a Car Counter



#### **Objectives**

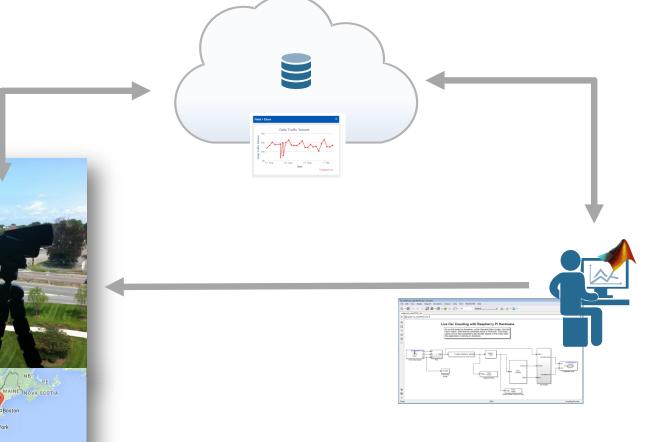
Measure, explore, discover traffic patterns

#### **Solution**

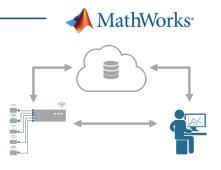
RaspberryPi 2+ webcam

Automated deployment of vision

algorithms on embedded sensor

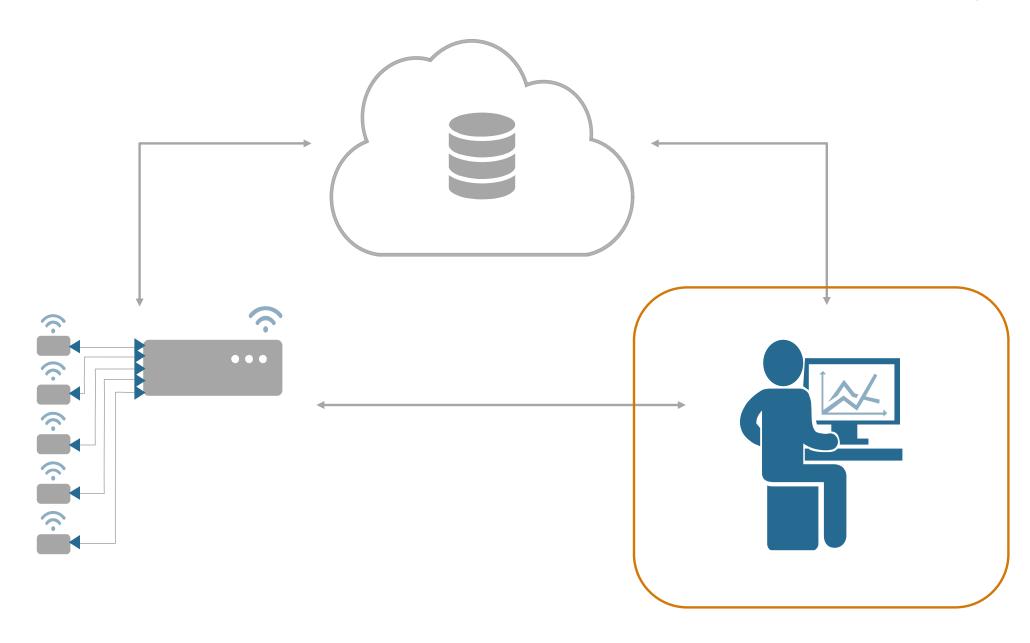


### Car Counter Setup





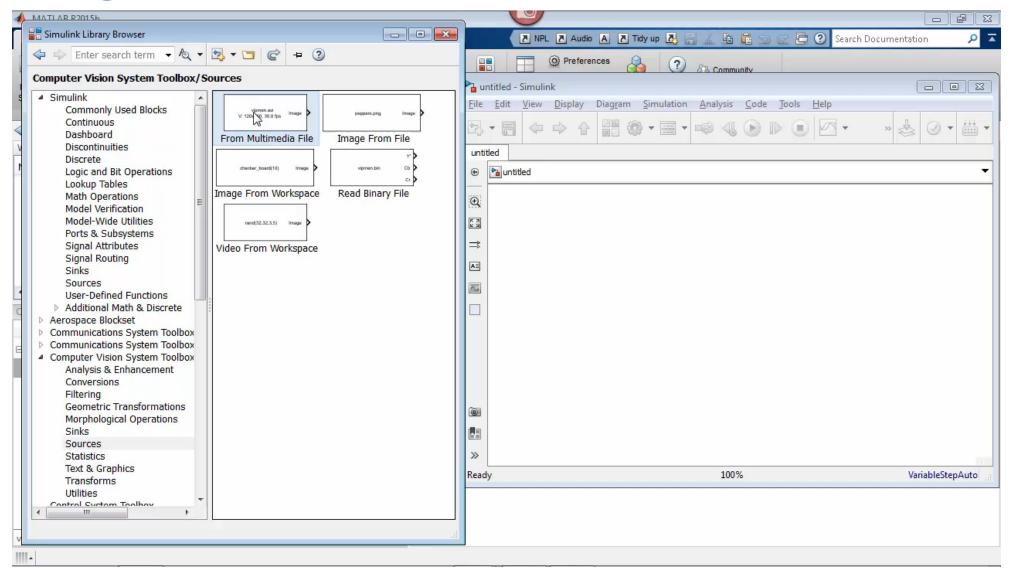






### Traffic sensor – step 1

### Design a car counter in Simulink





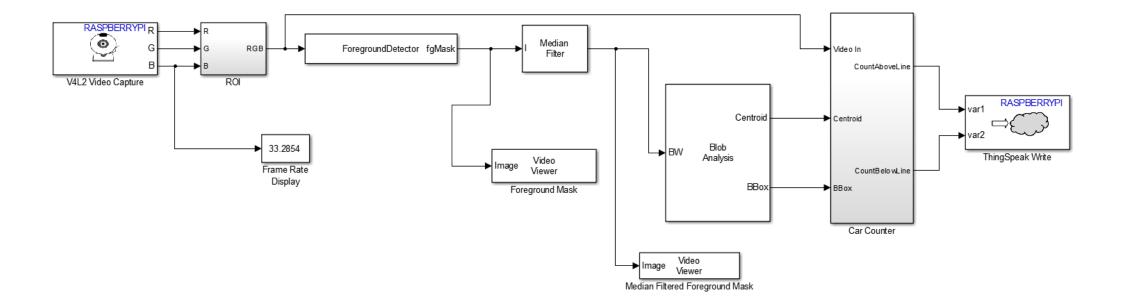


### Car Counting Algorithm

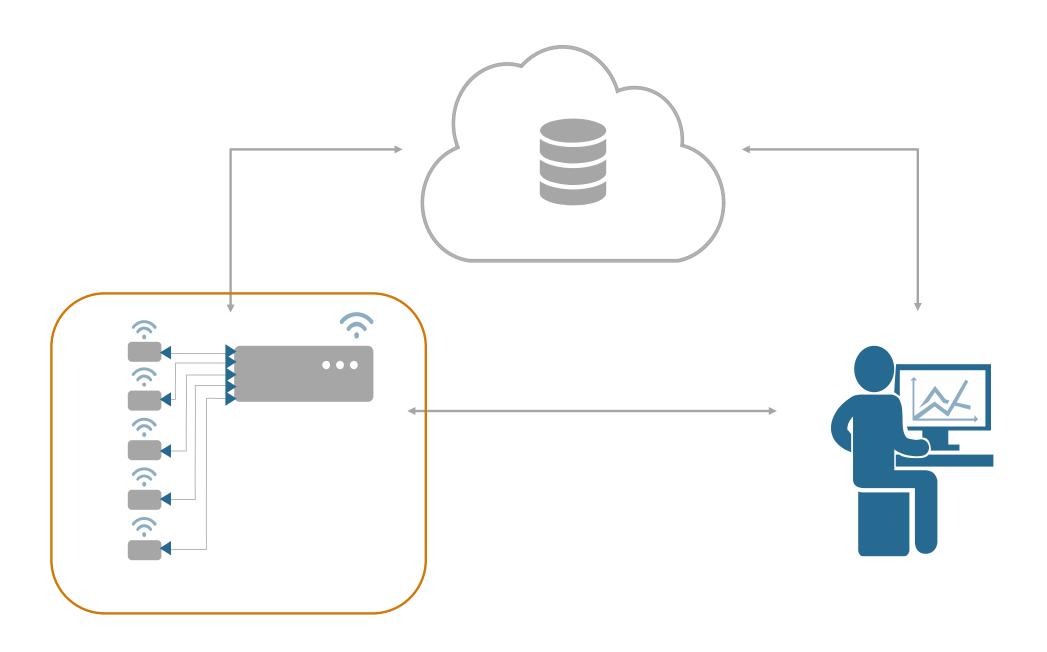


#### Live Car Counting with Raspberry Pi Hardware

To run this model on hardware, on the Simulink Editor toolbar, click the "Run" button. Note that the simulation mode is "External". This mode allows you to tune parameters and monitor signals in the model while the application is running on hardware.

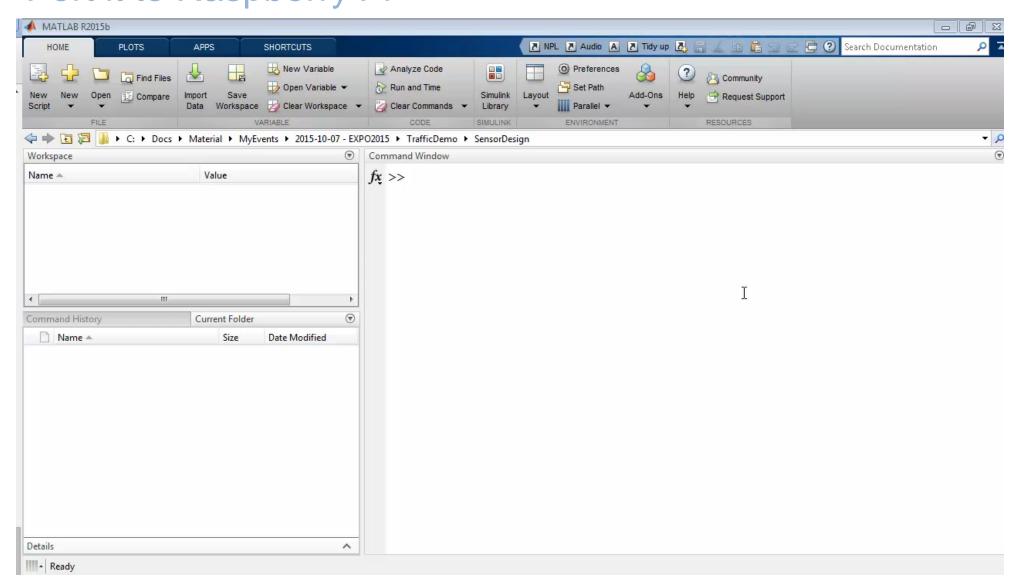


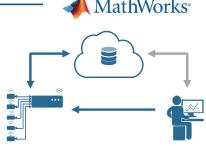






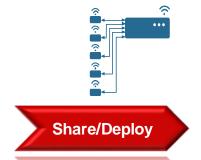
### Traffic sensor – step 2 Port it to Raspberry Pi







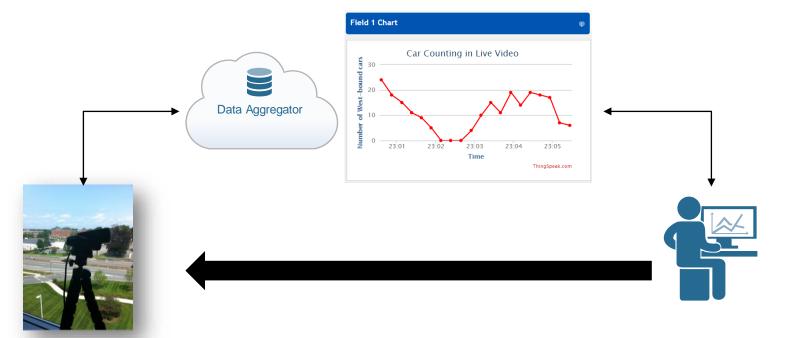
### MathWorks Support for Edge Nodes

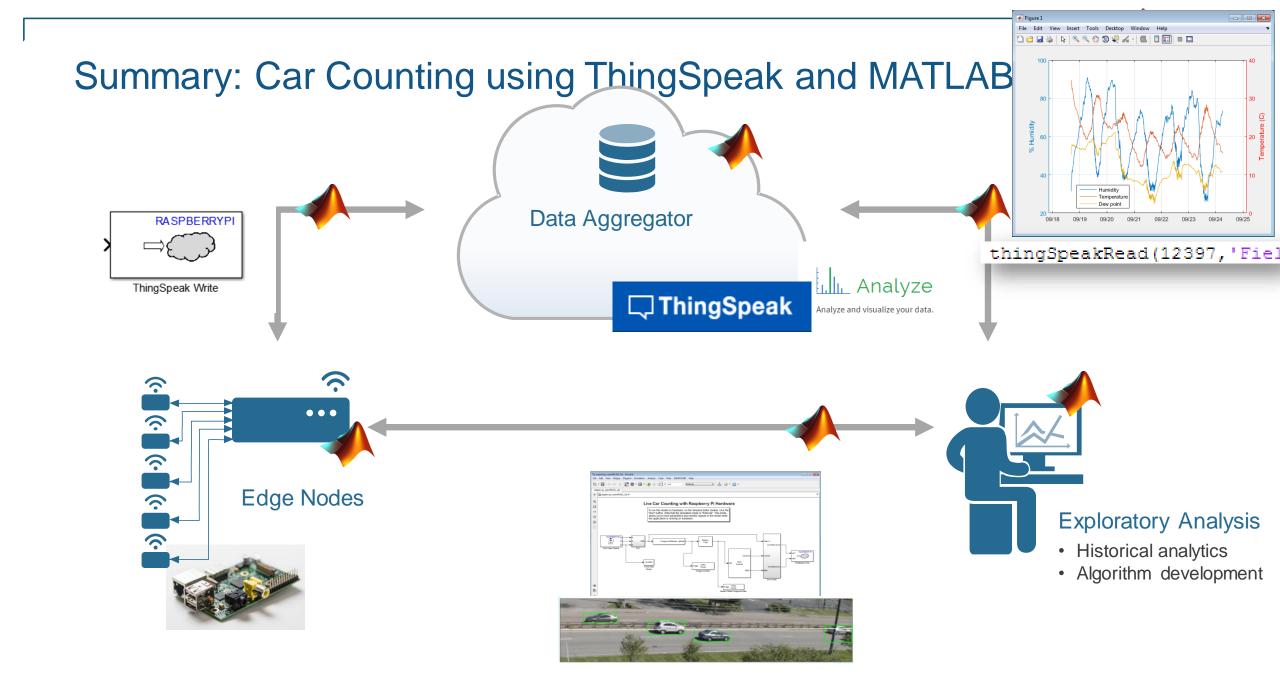


- MathWorks provides workflows to rapidly prototype and implement "smart" edge nodes.
- Why smart? Edge node processes the data before sending to aggregator

Video requires large bandwidth!

Embed the analysis on the edge node and just send the count instead



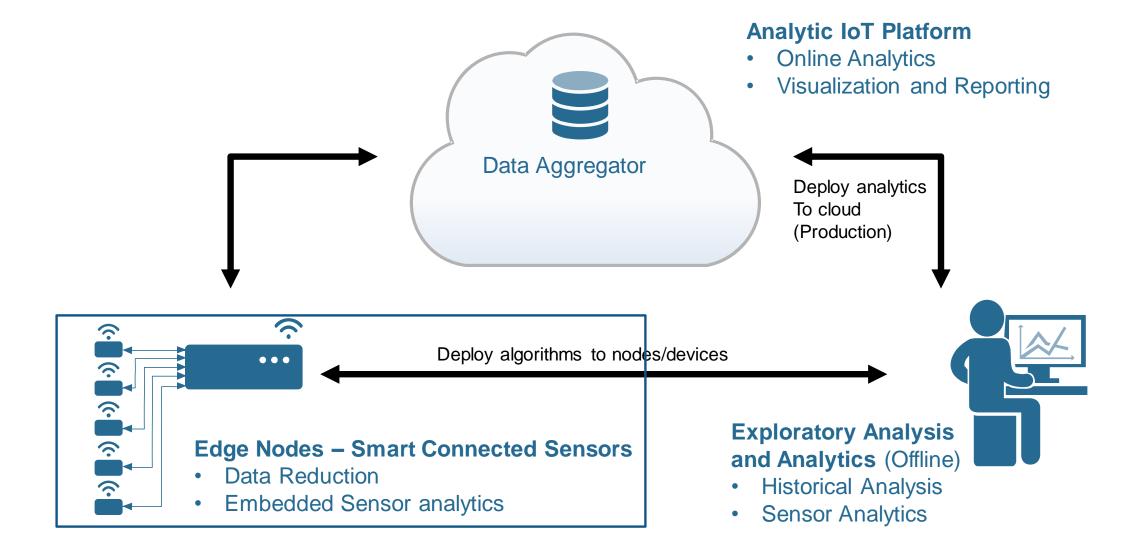




## MathWorks Offerings for Prototyping IoT Systems



### High Level Architectural View of IoT

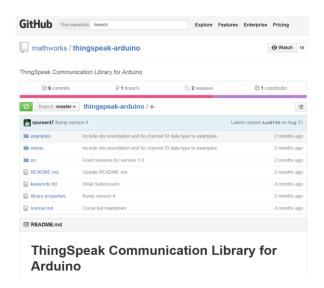




## Collect Getting data into ThingSpeak

Send sensor data to the cloud.

- Rest API
- **MQTT**
- **Native Libraries** 
  - Particle
  - Arduino
- Simulink Support Packages
  - Raspberry Pi
  - Arduino
  - BeagleBone Black





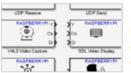
#### Arduino Support from Simulink

Create and run Simulink models on Arduino boards

Vendors: Arduino

Tags: C/C++ Code Generation, MathWorks Supported, Project-Based Learning, Run on Target Hardware, Support Package

Installer Enabled



#### Raspberry Pi Support from Simulink

Credit-card sized, low-cost, single-board computer with audio and video input/output, designed for teaching.

Vendors: Raspberry Pi

Tags: C/C++ Code Generation, MathWorks Supported, Project-Based Learning, Run on Target Hardware, Support Package Installer Enabled





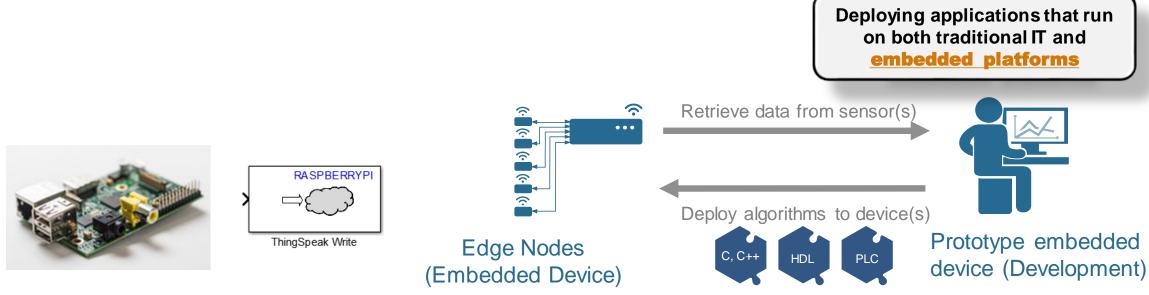
Send sensor data to the cloud.

### MathWorks Support for Edge Nodes



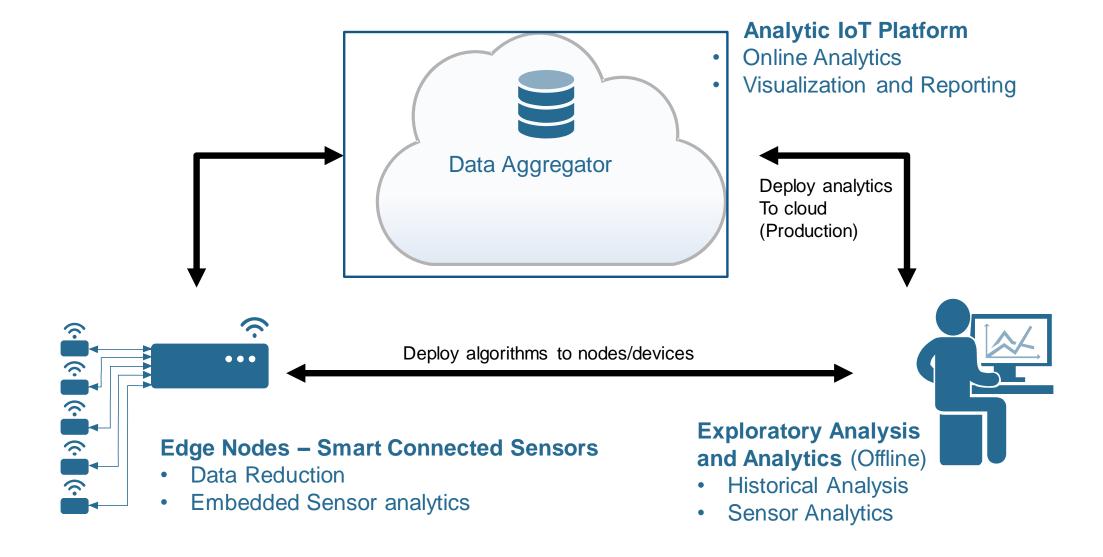
Share/Deploy

- MATLAB supports data acquisition from various hardware
- MathWorks has libraries for signal and image processing to accelerate development
- MathWorks supports automatic C/HDL/Structured Text code generation





### High Level Architectural View of IoT

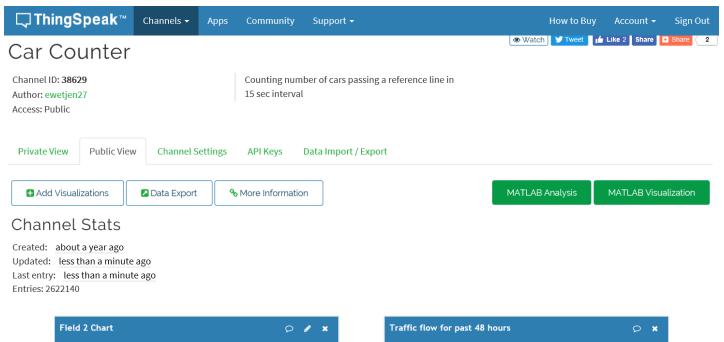




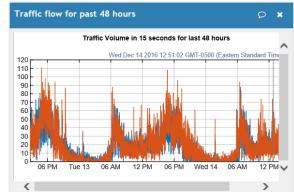


### ThingSpeak: Visualizing the Data

Analyze and visualize your data with MATLAB.







- Each field in each channel is provided with a default visualization which updates automatically based on the data coming in
- The default visualization contains iFrame code which can be used to embed the visualization and other applications
- Custom Visualizations can be added using the built-in MATLAB Analysis app

ThingSpeak Car Counter Channel

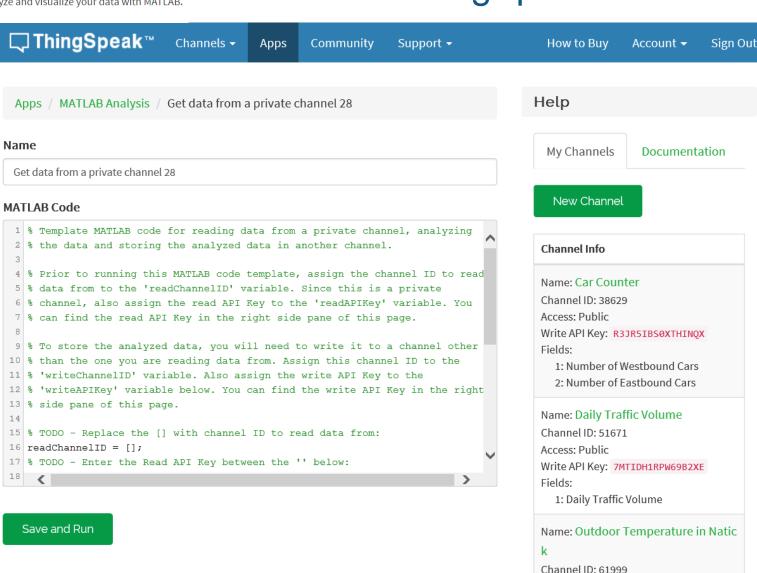




### MATLAB in ThingSpeak

Analyze and visualize your data with MATLAB

Output



Access: Public

Scheduled Online Analysis



# MATLAB Analysis in ThingSpeak What Toolboxes Work in ThingSpeak?

- Statistics and Machine Learning Toolbox™
- Curve Fitting Toolbox™
- Control System Toolbox<sup>™</sup>
- Signal Processing Toolbox<sup>™</sup>
- Mapping Toolbox<sup>™</sup>
- System Identification Toolbox™
- Neural Network Toolbox™
- DSP System Toolbox™
- Datafeed Toolbox<sup>™</sup>
- Financial Toolbox™

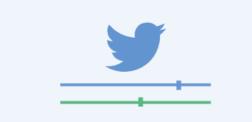






#### ThingTweet

Connect a device to Twitter® and send alerts.



#### TweetControl

Listen to the Twitterverse and react in real time.



#### TimeControl

Automatically perform actions at predetermined times with ThingSpeak apps.



#### React

React when channel data meets certain conditions.



#### TalkBack

Queue up commands for your device.



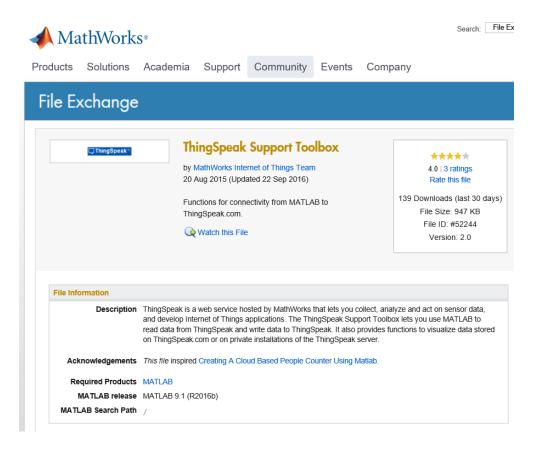
#### ThingHTTP

Simplify device communication with web services and APIs.



### Moving Data from ThingSpeak to Desktop MATLAB

- ThingSpeak Support Toolbox on FEX
- Same functions available in MATLAB Analysis App on ThingSpeak



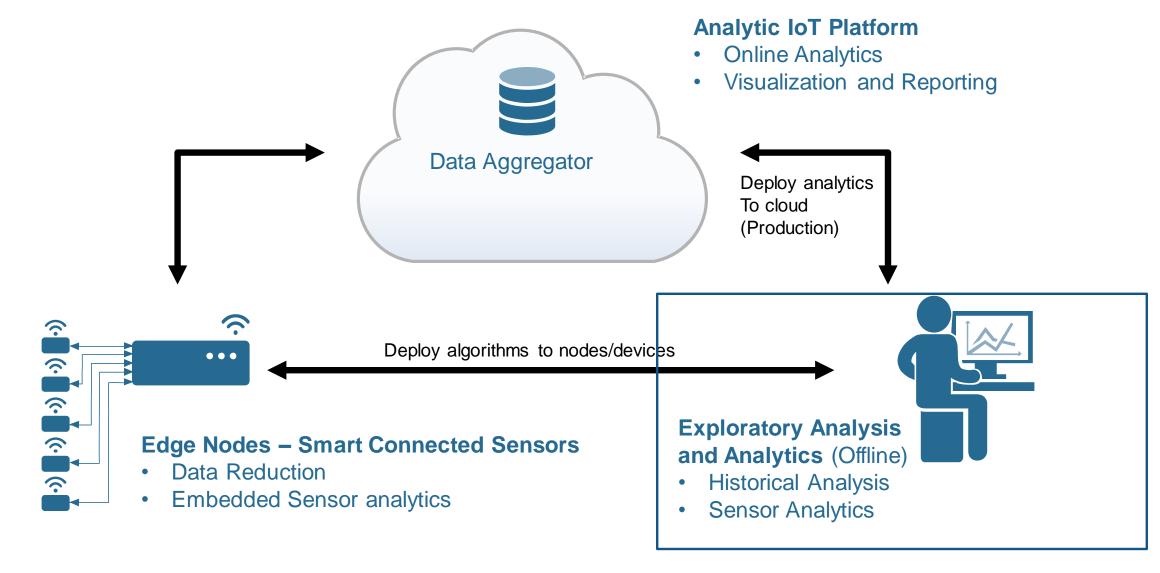
```
range = median(thingSpeakRead(22641,...
    'Fields',[1],'NumMinutes',5));

depth = round((3449 - range)/24.5,1);

thingSpeakWrite(50289, depth,...
    'WriteKey', '6RS44ZPWVI48QEKZ');
```



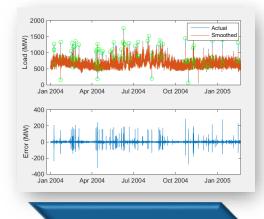
### High Level Architectural View of IoT

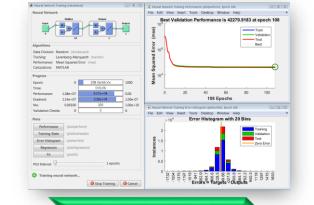


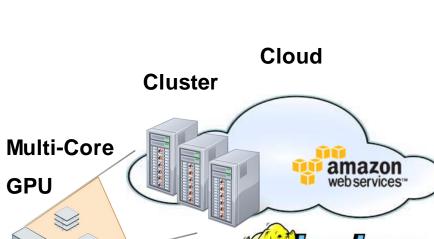


### **Exploratory Analysis & Data Analytics**







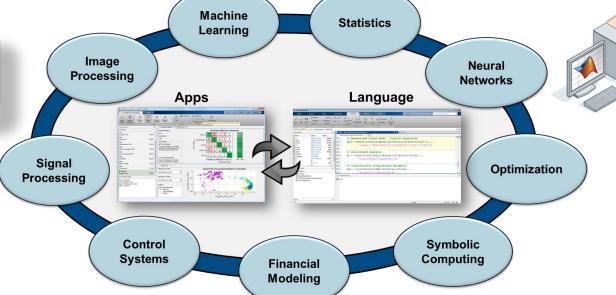


**GPU** 

**Preprocess Data** 

**Data Analytics** 

**Enable Domain Experts to be Data Scientists** 



**Scalable computation** 



# Big Data Capabilities in MATLAB Analyzing Historical Data Collected from Cloud- Exploratory Analysis

#### **Memory and Data Access**

- 64-bit processors
- Memory Mapped Variables
- Disk Variables
- Databases
- Datastores R2014b
- Image Datastores
- R2015b
- Spreadsheet Datastores
- R2016a

#### **Programming Constructs**

- Streaming
- Block Processing
- Parallel-for loops
- GPU Arrays
- SPMD and Distributed Arrays
- MapReduce R2014b
- Tall Arrays R2016b

#### **Platforms**

- Desktop (Multicore, GPU)
- Clusters
- Cloud Computing (MDCS on EC2)
- Chedoop
  - R2016h

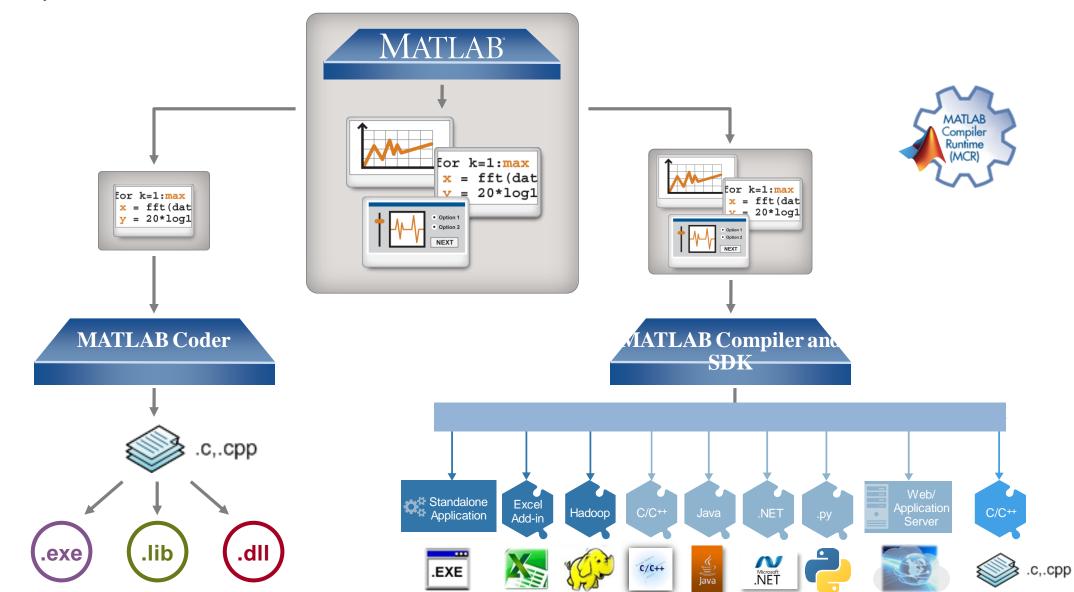
R2014b

Spark



### Integrate analytics with your enterprise systems

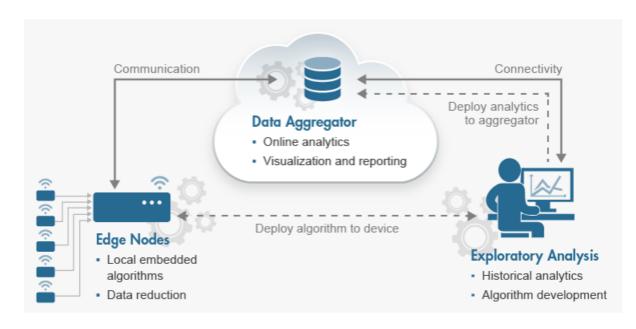
MATLAB Compiler and MATLAB Coder





### ThingSpeak

- Free online data aggregation platform
  - Typically used to collect data from sensors ("Things")
  - Provides instant visualization of the data
  - Popular for people experimenting in IoT
- Can be used to act on data
  - E.g. Tweet a message when the temperature in your backyard reaches 32 degrees
- Can be used to analyze data
  - MATLAB integration allows users to run scheduled MATLAB code on data coming into ThingSpeak





Send sensor data to the cloud.



Analyze and visualize your data.



Trigger a reaction.



### MATLAB for IoT Prototyping

- ThingSpeak
  - Easy to get started
  - Designed for engineers and scientists
  - Integrated MATLAB visualizations and analytics
- Integrated workflow from a single environment
  - Access → Rapid/Iterative Analysis → Deployment
- Leverage parallel computing to scale-up your analytics to large datasets
- Eliminate need to recode by deploying/embedding algorithms into sensors or production



# Cadmus Collects and Analyzes Energy Data in Near Real Time Using MATLAB and the ThingSpeak Internet of Things Platform

#### Challenge

Measure and evaluate the energy efficiency of residential homes and factories based on data from onsite sensors

#### **Solution**

Use ThingSpeak to collect up-to-the-minute temperature, humidity, and power usage data and use MATLAB to analyze and visualize the data

#### Results

- Market opportunity seized
- Development effort cut by two-thirds
- Sensor networks quickly deployed



Internet of Things system using ThingSpeak for collecting and analyzing energy data

"With ThingSpeak we were able to quickly develop and improve upon our designs because the platform makes iterations easy, is stable, and scales well. Other platforms are available for collecting and analyzing data, but none met our needs as fully and immediately as MATLAB and ThingSpeak."

Dave Korn
Cadmus

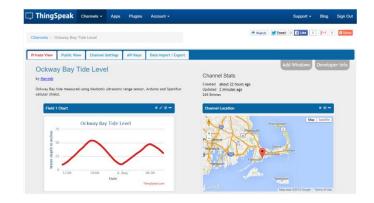


How do you get started?



#### **Additional Resources**

- ThingSpeak Blog: http://community.thingspeak.com/
  - Latest information on ThingSpeak
- MATLAB Central : http://www.mathworks.com/matlabcentral/
  - ThingSpeak Support Toolbox
  - Simulink Support Package for Raspberry Pi Hardware
- MakerZone Articles: http://makerzone.mathworks.com/
  - Analyzing Weather Data from an Arduino-Based Weather Station
  - Weather Station Revisited
  - Real-Time Tide Gauge to Tweet Tide Alerts
  - Counting Cars and Analyzing Traffic





## THANK YOU



### Data Analytics tools with MATLAB

