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Developing Analytics and Deploying IoT Systems

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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

More comfort, convenience, performance, increased safety, low risk etc.
‘Chips in everything’ & the rise of ‘Ubiquitous sensing’
Extracting insights from sensor data... a common practice

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
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

DATA - Billions of data points:
Physics, energy cost, power, internal temperatures, ambient temperatures, ambient humidity, building operation schedule, comfort bounds, etc.

Analytics and Machine Learning
plus system identification, control theory & more

Predictive Model
deployed on cloud with client system and real-time data feeds
Example – BuildingIQ
Cloud based adaptive building energy management

After: 25% cost reduction

Before
High Level Architectural View of Internet of Things

Communications Network

Deploy analytics to server/cloud

Smart Connected Devices

Deploy algorithms to nodes/devices

Data Aggregation & Analytics

Algorithm Development Sensor Analytics

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IoT Challenges

Need IT expertise to integrate analytics on cloud. Can I prototype my IoT solution first?

Need variety of data for analysis. How to get started?

Communications Network

Data Aggregation & Analytics

Multi-Disciplinary Workflow

Deploy analytics to server/cloud

How do I deploy my algorithms on a smart device / cloud?

Algorithm Development

Sensor Analytics

Predictive algorithm? Do I need to be Data Scientist?

Deploy algorithms to nodes/devices

Smart Connected Devices

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How MathWorks Addresses IoT Challenges?

1. MATLAB makes it easy to acquire both business and engineering data.
2. Enable Domain Experts to be Data Scientists.
3. Provides a platform for prototyping IoT systems or small scale deployment with no web infrastructure needed.
4. Deploying applications that run on both traditional IT and embedded platforms.

Data Aggregation & Analytics

Communications Network

Deploy analytics to server/cloud

Deploy algorithms to nodes/devices

Algorithm Development

Sensor Analytics

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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

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Get Started with IoT by Accessing Sensor Data in MATLAB

- Analog Input
  - Serial Port
  - TCP/IP
  - UDP

Prototyping is an important step in developing IoT system. You need only a sensor and MATLAB to get started.
Example 1: Weather monitoring using ThingSpeak and MATLAB

“It’s hot out!! Don’t forget to carry a bottle of water”
What Is ThingSpeak?

Web Site For People

Web Service for Devices

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{  
  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",  
    fields: ["Number of Westbound Cars", "Number of Eastbound Cars"],  
    created_at: "2015-05-19T20:14:03Z",  
    updated_at: "2016-05-10T10:36:35Z",  
    last_entry_id: 1477231  
  },  
  feeds: [  
    {  
      created_at: "2016-05-19T10:36:20Z",  
      entry_id: 1477230,  
      fields: ["18.000000", "0.000000"]  
    },  
    {  
      created_at: "2016-05-19T10:36:35Z",  
      entry_id: 1477231,  
      fields: ["18.000000", "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

https://thingspeak.com
Example 1: Weather monitoring using ThingSpeak and MATLAB

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

**Access and Explore Data**
- Files
- Databases
- Sensors

**Preprocess Data**
- Working with Messy Data
- Data Reduction/Transformation
- Feature Extraction

**Develop Predictive Models**
- Model Creation e.g. Machine Learning
- Parameter Optimization
- Model Validation

**Integrate Analytics with Systems**
- Desktop Apps
- Enterprise Scale Systems
- Embedded Devices and Hardware
Example 2: Low Tide Prediction Using MATLAB And ThingSpeak

Predicated and Measured Ockway Bay Tide Chart

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

Historical
and tide

Neural Wind Forecast

Predicted and Measured Ockway Bay Tide Chart
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™
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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

Connect and Acquire  Signal Processing  Machine Learning  Embedded Implementation
Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow
Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow

Signal Processing and feature extraction

Fourier Spectrum

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Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow
Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow
Example 3: Sensor Analytics and Development of Smart Connected Devices - Workflow
Example 3: Summary of Sensor Analytics Development and Deployment
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.
Examples for Today

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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.mathworks.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
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

External Data & Business Systems

Deploy analytics To cloud

Ingest  Store  Compute

Smart Connected Devices

Algorithm Development Sensor Analytics

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Integrating MATLAB with Third Party IoT Cloud Platforms
Integrating MATLAB in Large Scale Production Systems

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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
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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