

ThingSpeak and the Internet of Things (IoT)

Dhirendra Singh | Deepak Sharma

MathWorks India

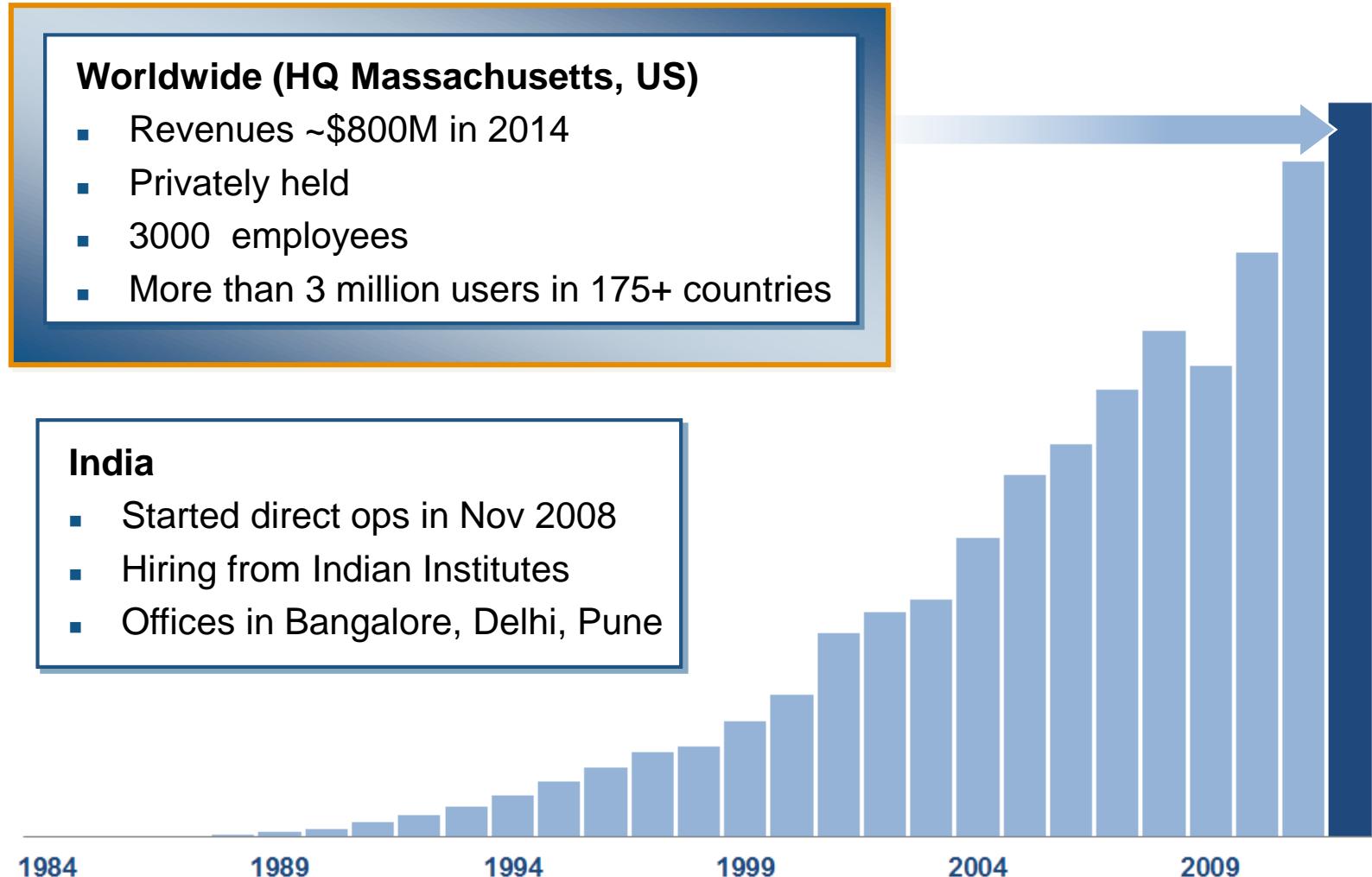
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Agenda

- What is IoT?
 - Market Drivers and Challenges
 - Introduction to ThingSpeak
 - Examples
 - Other IoT examples using MW tools
 - MATLAB and Simulink Capabilities for IoT
- Modeling of Mechatronics Systems
 - Mechanical engineering concepts using Simscape (Physical Modeling)
 - Multi-Body Dynamics Simulation using SimMechanics
 - Control system design and analysis
 - Implement Control on Low cost hardware - Arduino
 - Demo of Robot arm
- Machine Learning & Data Analytics
 - Accessing, exploring, analyzing, and visualizing data in MATLAB
 - Neural networks for Data driver modeling
 - Using the Classification Learner app and functions in the Statistics and Machine Learning Toolbox to perform common machine learning tasks such as Feature selection and feature transformation
 - Demo: ADAS using live camera stream

MathWorks Today

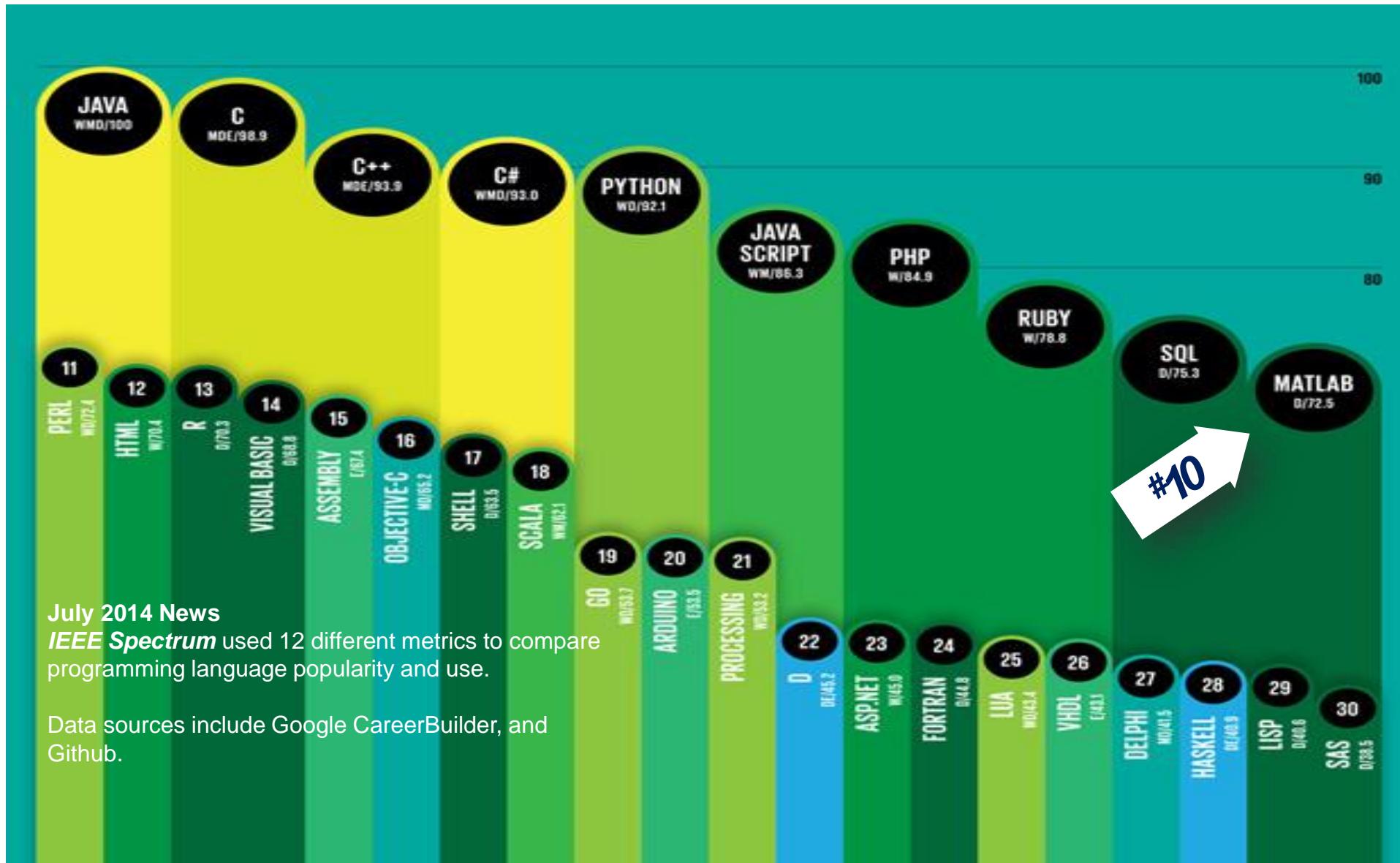


Key Industries

- **Aerospace and Defense**
- Automotive
- Biotech and Pharmaceutical
- Communications
- **Education**
- Electronics and Semiconductors
- Energy Production
- Financial Services
- Industrial Automation and Machinery



The Right Language for the Task



Supporting Innovation MATLAB Central

- Open exchange for the MATLAB and Simulink user community
- 800,000 visits per month
 - 50% increase over previous year
- File Exchange
 - Free file upload/download, including MATLAB code, Simulink models, and documents
 - File ratings and comments
 - Over 9,000 contributed files, 400 submissions per month, 25,500 downloads per day
- Newsgroup and Web Forum
 - Technical discussions about MATLAB and Simulink
 - 200 posts per day
- Blogs
 - Read posts from key MathWorks developers who design and build the products

The screenshot shows the MATLAB Central homepage. At the top, there's a navigation bar with links for File Exchange, Newsgroup, Link Exchange, Blogs, Contest, and MathWorks.com. It also shows that the user is logged in as Jim and provides a search bar.

The main content area is divided into several sections:

- File Exchange:** A large section featuring "The Latest from MATLAB Central" with links to "Video How to download from File Exchange directly in MATLAB", "Check-out File Exchange's new categories", and "Download MATLAB Central Screensaver". Below this is a "TRIAL SOFTWARE" section for MATLAB & SIMULINK.
- Newsgroup:** Described as "An open forum for everyone in the MATLAB and Simulink universe", it includes a "Post a Message" button and a "RECENT POSTS" section listing various MATLAB-related topics.
- Blogs:** A section titled "Blogs" featuring "Weekly commentary from the people who design and build MathWorks products". It includes sections for "RECENT UPDATES", "MIKE ON THE MATLAB DESKTOP", "FILE EXCHANGE PICK OF THE WEEK", "LOREN ON THE ART OF MATLAB", "SETH ON SIMULINK", and "STEVE ON IMAGE PROCESSING", each with a thumbnail, title, and a "View archive" link.
- Link Exchange:** A section titled "Links for users of MathWorks products in research, industry, and academia" with categories like academic, language, and engineering.

Classroom Resources at mathworks.in

[Academia main page](#)

[Classroom Resources](#)

Resources by Topic

- [Communication Systems](#)
- [Computational Biology](#)
- [Computational Finance](#)
- [Computational Methods](#)
- [Control Systems](#)
- [Digital Signal Processing](#)
- [Embedded Systems](#)
- [Image and Video Processing](#)
- [Measurement and Instrumentation](#)
- [Numerical and Symbolic Math](#)
- [Programming and Computer Science](#)
- [Project-Based Learning](#)

Robotics and Mechatronics

Classroom Resources

Use MATLAB and Simulink to teach key areas in robotics and mechatronics, such as:

- Kinematics and dynamics
- Motor control and computer vision
- Multi-domain simulation and optimization
- Electromechanical systems

Search all classroom resources.

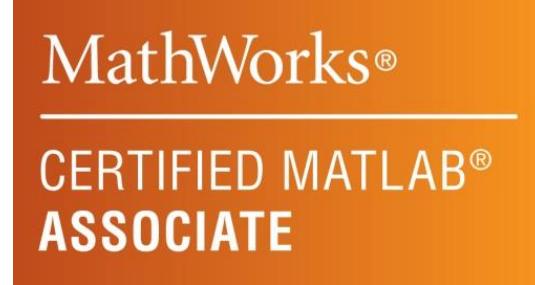
 [Teaching Mechatronics Using MATLAB and Simulink \(Video\)](#)

Group by Department

Submit Resources

Title	Summary	Resource Type
Simulink models and demo hardware for control design (from B & R Automation)	Simulink models for Airball and Reaction Wheel Pendulum systems	Downloadable code or models
MATLAB and Simulink interface to a Robotino® mobile robot system	MATLAB and Simulink libraries to control a Robotino robot over a USB or TCP/IP interface	Downloadable code or models
LEGO MINDSTORMS NXT Software for MATLAB and Simulink	MATLAB toolboxes for USB & wireless (Bluetooth) control; Simulink blocksets for NXT code generation	Downloadable code or models
Quanser - Hardware/Software solutions for teaching mechatronics	Integrated hardware/software solutions (based on Simulink) and course material for mechatronics	Course materials
Teaching Mechatronics Using MATLAB and Simulink	Webinar on using Simulink to model, analyze, and visualize mechatronic systems	Video
MATLAB Toolbox for the iRobot Create Mobile Robot	A MATLAB toolbox for controlling an iRobot Create over a serial port or Bluetooth wireless	Downloadable code or models

Training Certification



- Accelerate professional growth
- Validate proficiency with MATLAB
- Increase productivity and project success

MathWorks Certified MATLAB Associate Examination Bangalore

Available Onsite

Recommended Courses
MATLAB Fundamentals (MLBE)

Email: training@mathworks.in

URL: <http://www.mathworks.in/services/training>

Phone: 080-6632-6000

Total Academic Headcount (TAH)

- Provides access to our products for every faculty, staff and student in a college or university
- Two License Options to choose from*:
 1. Campus: Allows for campus wide access on university owned machines to all faculty, staff and students. Faculty and staff can use software at home.
 2. Student: Allows for student use on their personal computers.
- TAH Agreement (wraps around standard SLA) and requires custom quoting, price is customer specific

*Pilot in process for combined Campus/Student Offering in select countries

My Information

Dhirendra Singh

- AE – CDA
- Delhi
- Mechanical Engineer

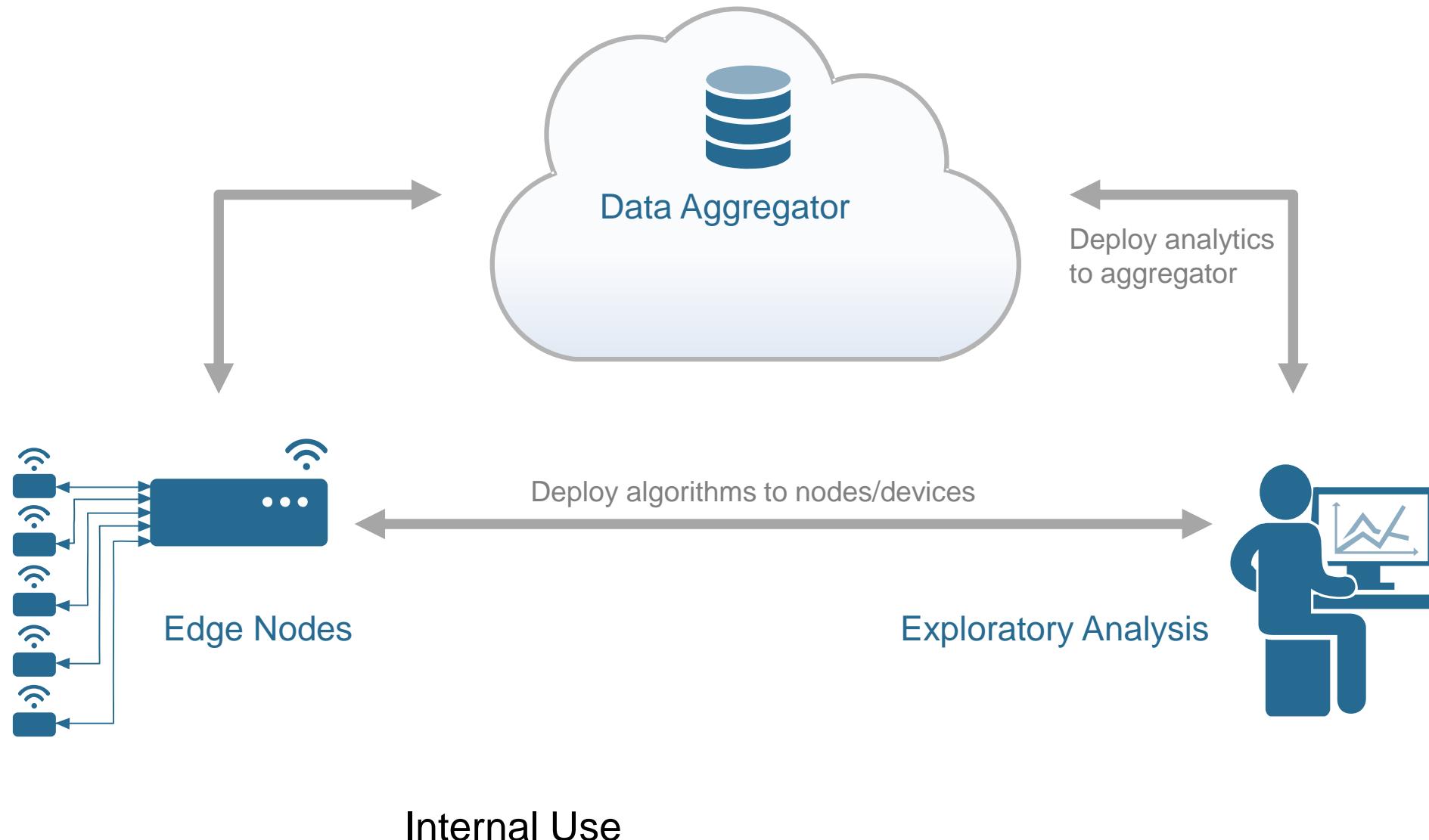
Areas:

- Controls & Automation
- Robotics
- Physical modeling
- Signal processing & Communication

Agenda

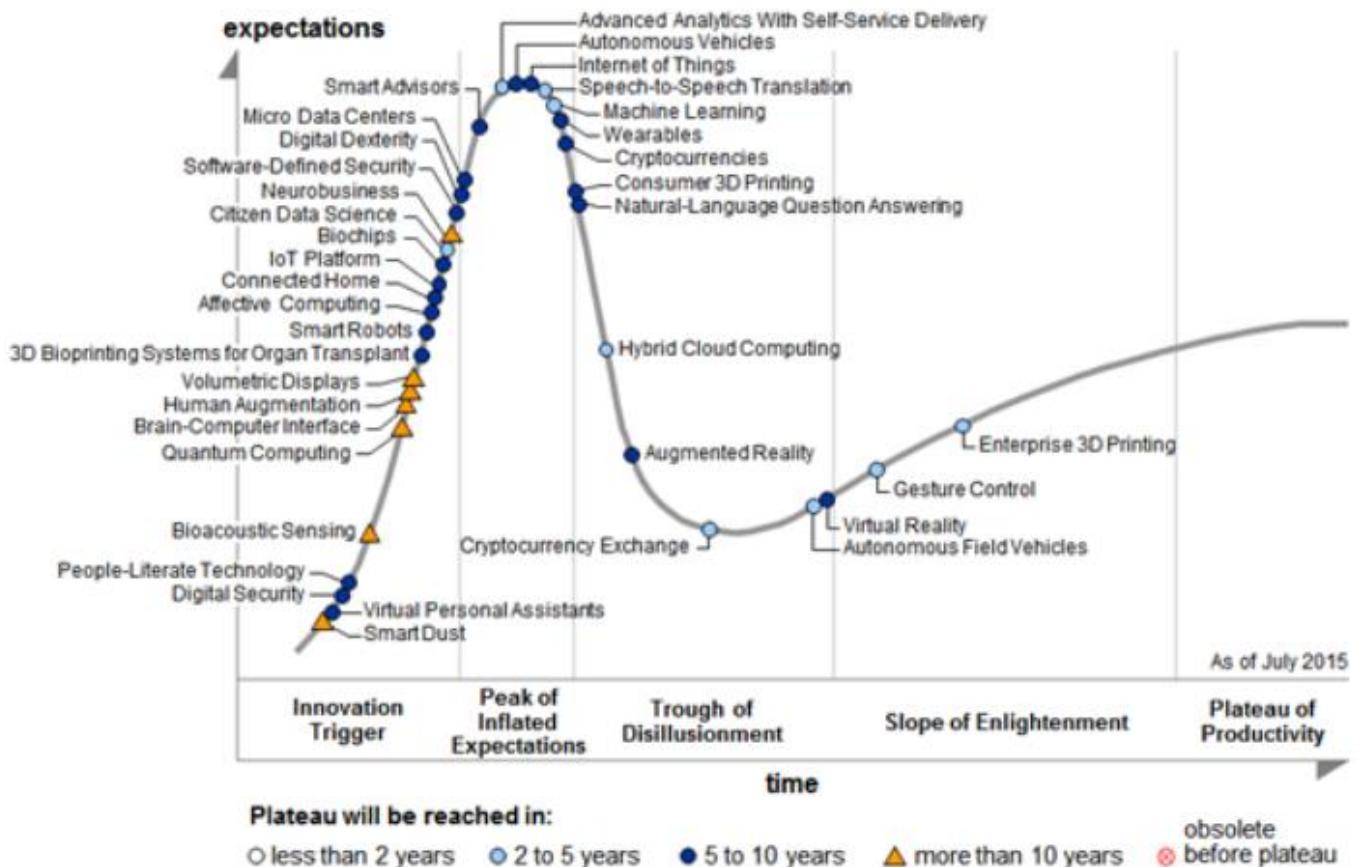
- What is IoT?
- Market Drivers and Challenges
- Our Response
- Introduction to ThingSpeak
 - Examples
- Other IoT examples using MW tools
- MATLAB and Simulink Capabilities for IoT
- Summary

What is the Internet of Things?



Trends Driving IoT

- Cheap sensors
- Cheap computing power in the Cloud
 - Big Data
- Promise of business value
 - Improved efficiencies
 - New services



Markets Driving IoT

- Smart Cities
- Connected Cars
- Smart Meters
- Retail
- Wearables
 - Healthcare
 - Personal technology
- Industrial IoT
 - M2M
- Smart Agriculture

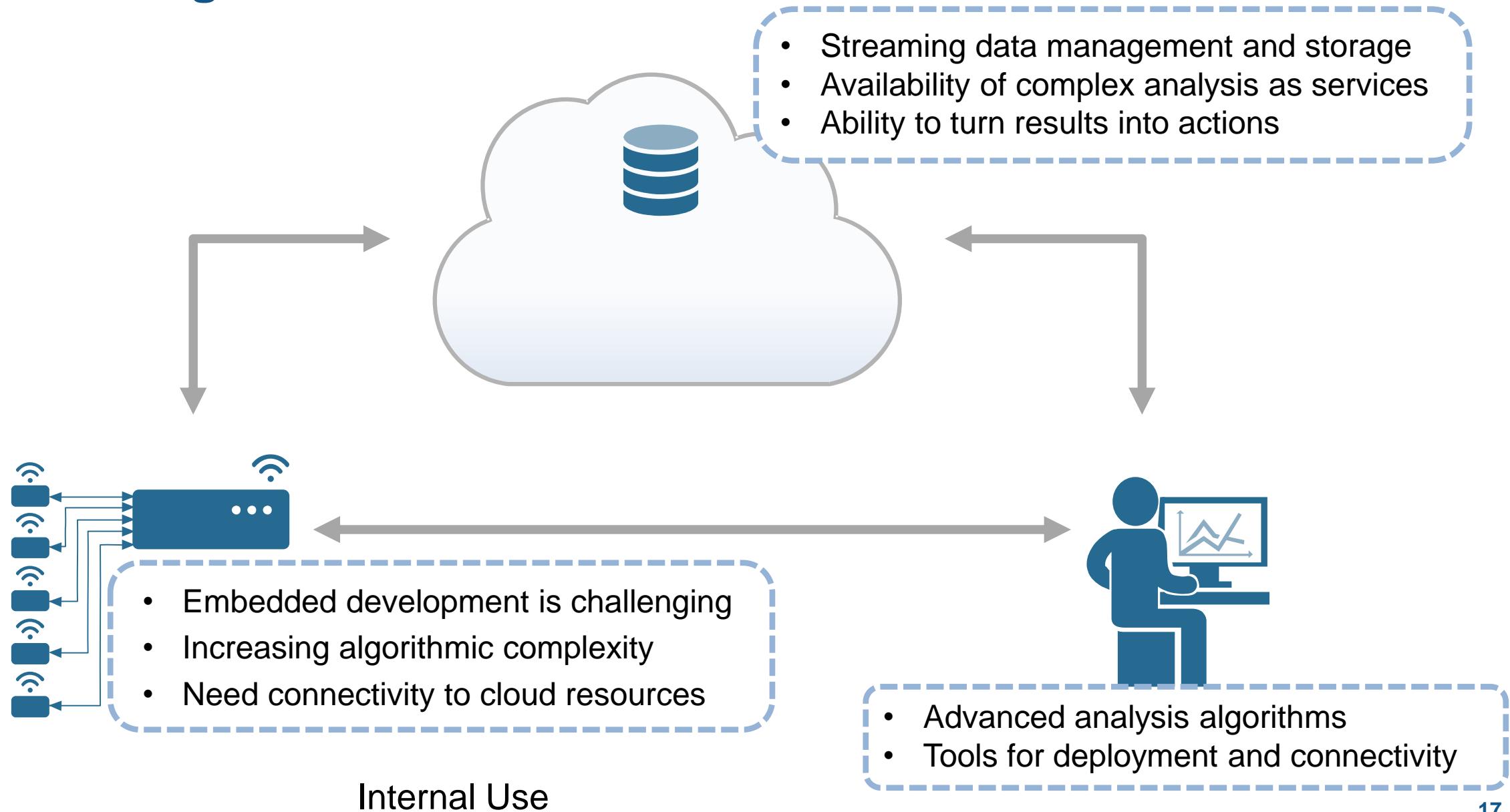
Market Situation

- IoT growing at 30% CAGR today
 - Multiple independent sources
 - McKinsey Study 2015
 - IoT will be an 11.1 Trillion Dollar Market by 2025
 - On average, 40 percent of the total value that can be unlocked requires different IoT systems to work together.
 - Most IoT data collected today are not used, and the data that are used are not fully exploited
 - Nucleus Research 2016
 - Advanced analytics customers experience 2.2 times more ROI than traditional BI customers
 - Customers should be able to at least pilot an IoT solution within 9 months for a respectable payback period.
- **Analytics is key to getting value of IoT system**
- **Prototyping is hard**

Challenges of IoT

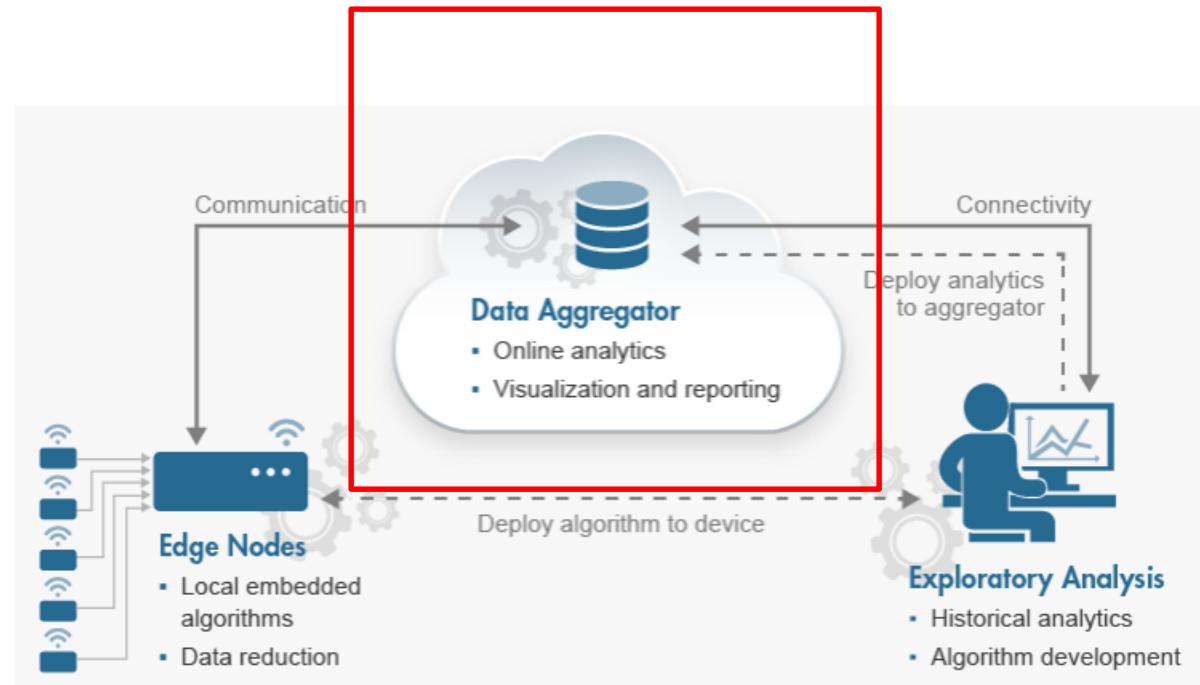
- Complex systems
 - Hard to get started
- No single vendor solutions
- Multiple expertise required to build a system
 - Firmware
 - Communications
 - Web/ IT
 - Data Science
- Lack of consolidation on Industry Standards

IoT Challenges



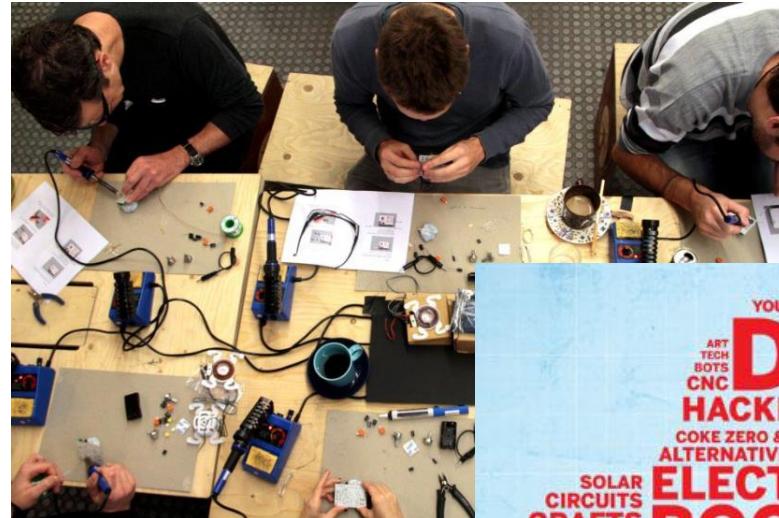
What is ThingSpeak?

- 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
 - Has more than 50,000 users
- Can be used to analyze data
 - New MATLAB integration allows users to run scheduled MATLAB code on data coming into ThingSpeak
- Can be used to act on data
 - E.g. Tweet a message when the temperature in your backyard reaches 32 degrees



Who is ThingSpeak for today?

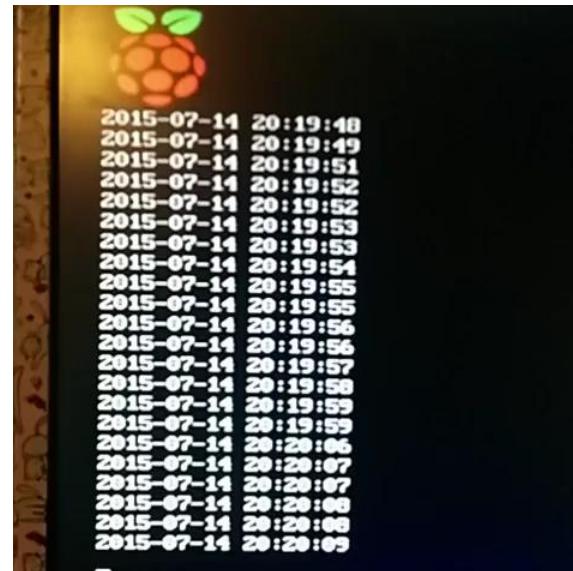
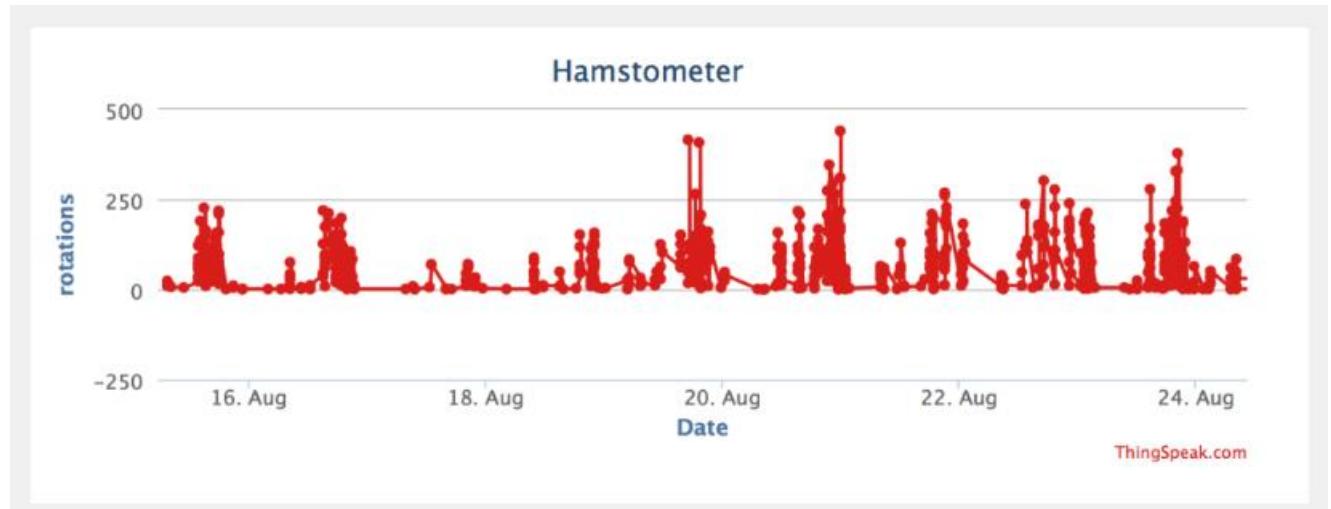
- Makers
- EDU
- Engineers prototyping



<https://thingspeak.com/>

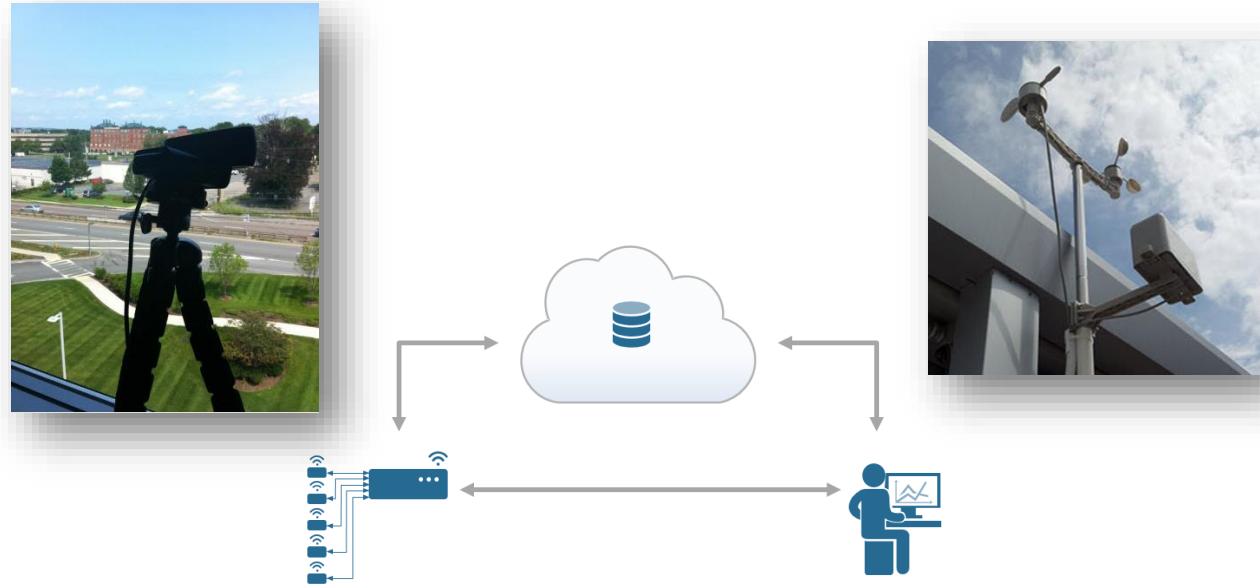
Common ThingSpeak applications

- Environmental Monitoring
- Server Room Monitoring
- House Monitoring
- Rodent tracking



Some IoT examples

- Two all-in-MATLAB IoT examples



- Scaling up MATLAB to IoT – the whole picture

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%

MATLAB EXPO 2015
UNITED KINGDOM

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

MATLAB EXPO 2015
UNITED KINGDOM

21

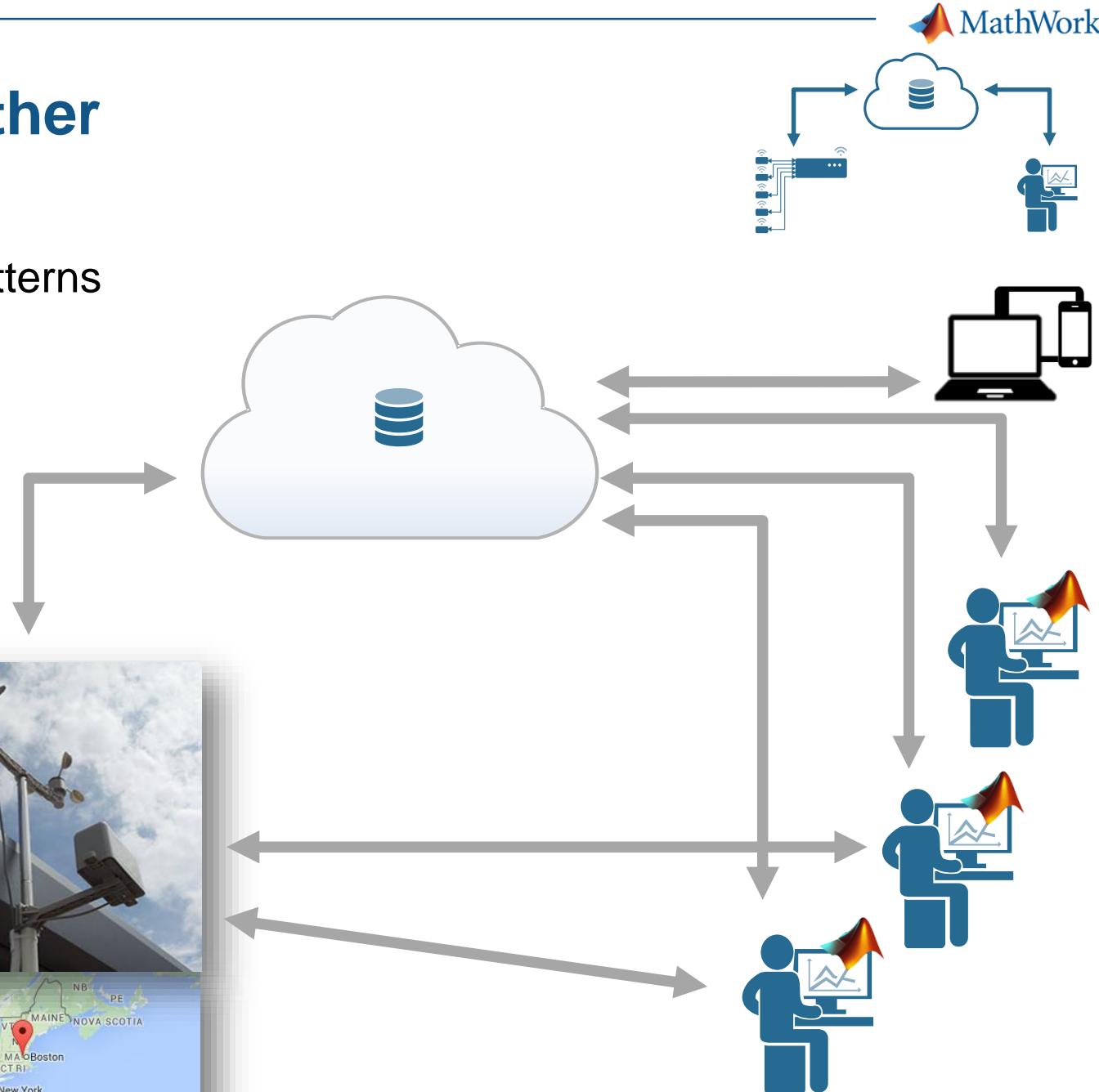
Example 1: Monitoring Weather

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



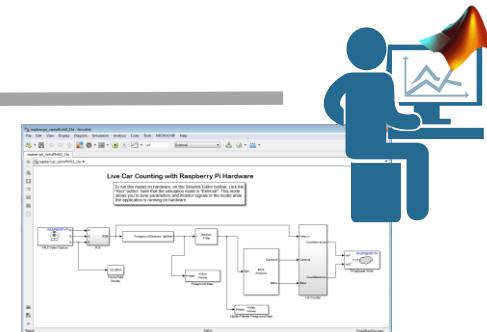
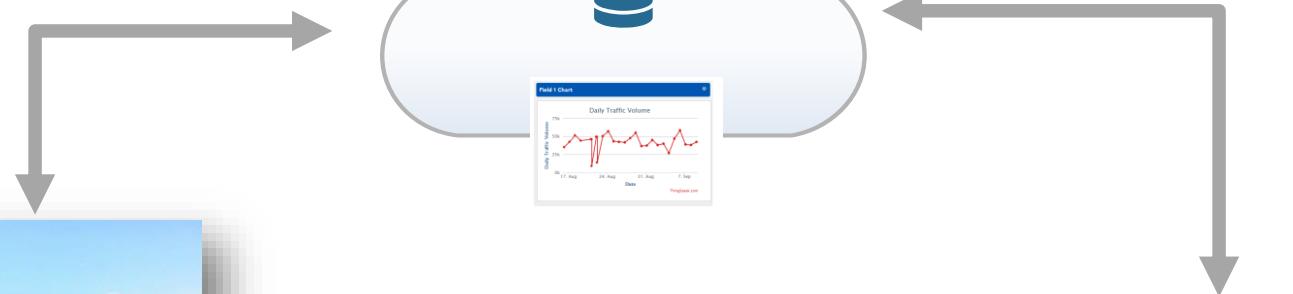
Example 2: Monitoring Traffic

Objectives

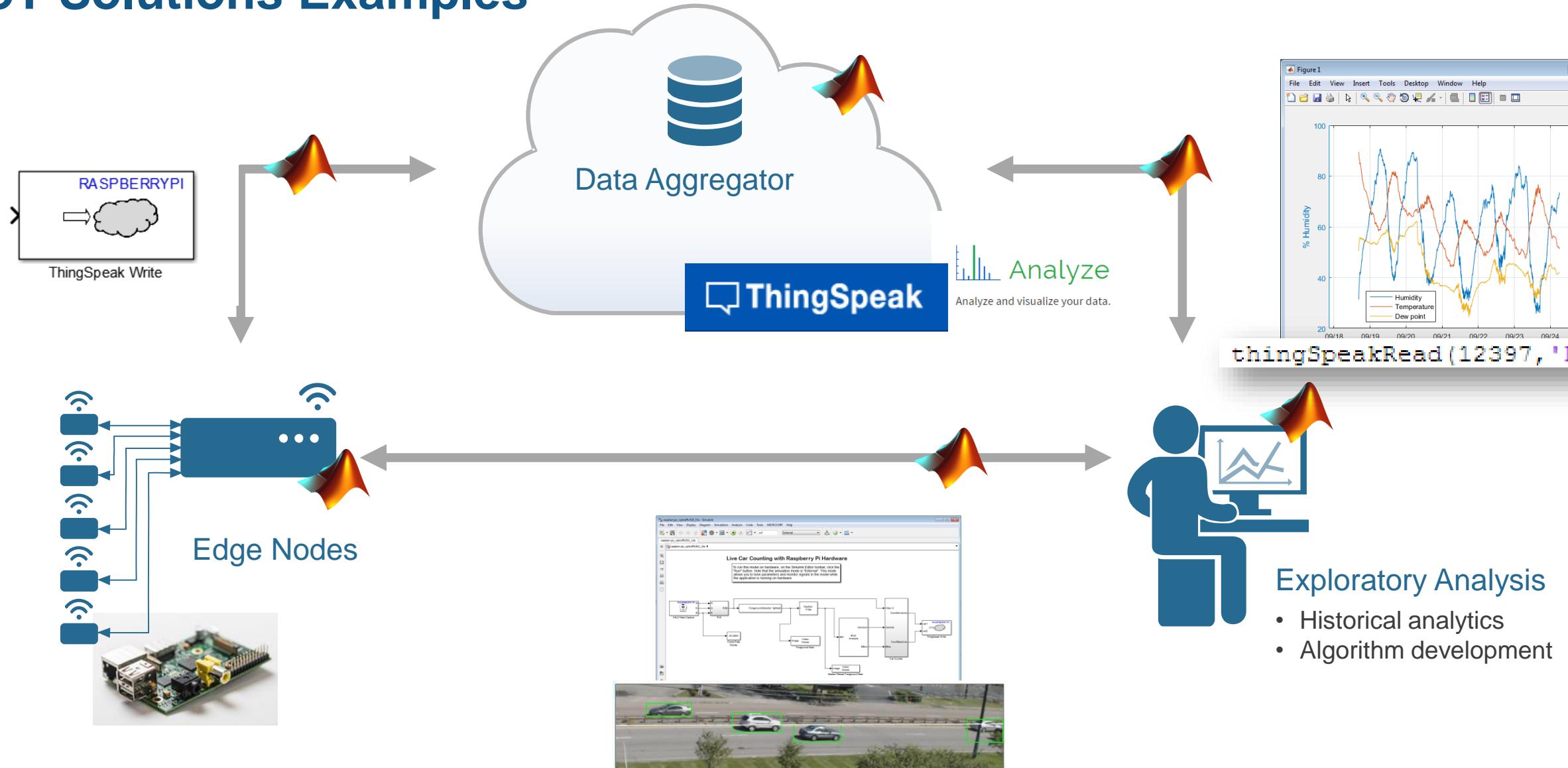
- Measure, explore, discover traffic patterns
- Provide live local traffic information service

Solution

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



IoT Solutions Examples

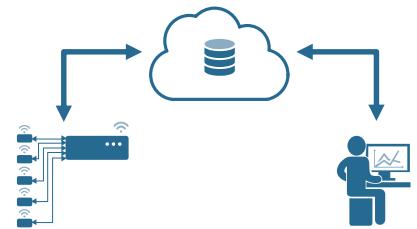


Internal Use

Customer Study: BuildingIQ Predictive Energy Optimization

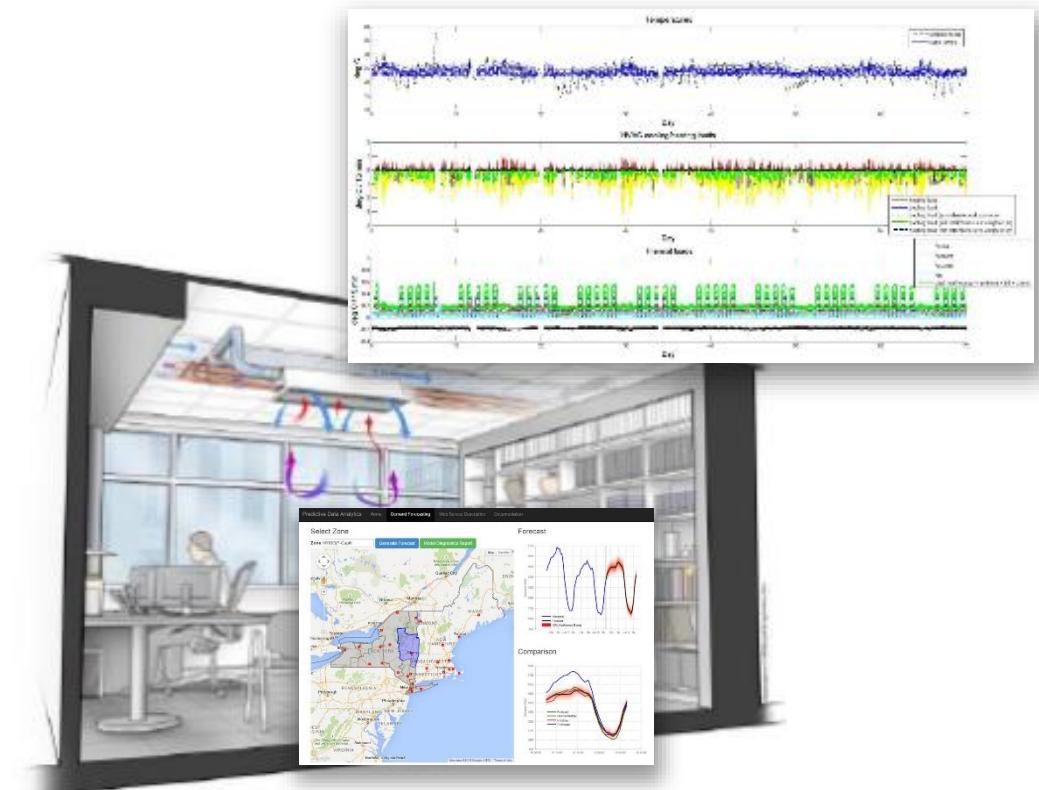
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Benefit

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Customer Study: iSonea

Cloud and Embedded Analytics

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iSonea



Summary

- IoT is rapidly changing, emerging application area
- Analytics are important
- With ThingSpeak, you can develop lightweight IoT systems entirely in MATLAB
 - Targeting Makers now, but soon commercial users
 - Goal is to introduce MATLAB as the language for IoT Analytics
- MathWorks tools address many of the challenges across the IoT diagram so there is opportunity
- We can add value
 - MATLAB language to develop algorithms
 - Simulink for deploying algorithms on the edge devices
 - Ease the on-ramp for prototyping with ThingSpeak

Design & Deploy Control Algorithm for Mechatronic Systems

Dhirendra Singh

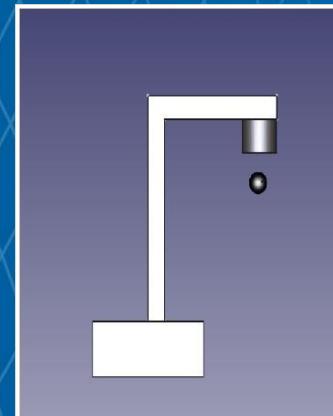
Application Engineer

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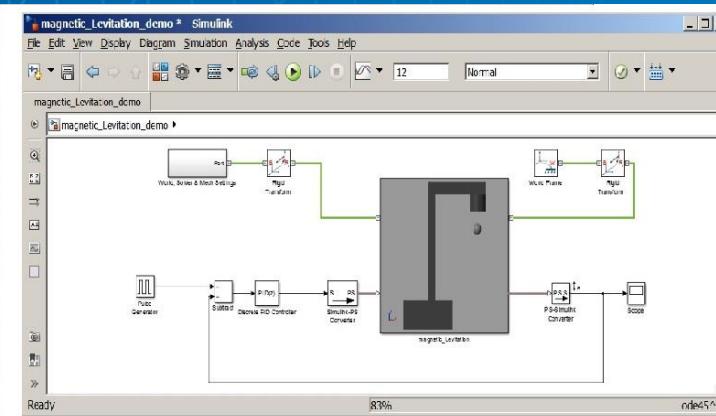
Deepak Sharma

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CAD File



(import)

Simulink Model

(code generation)



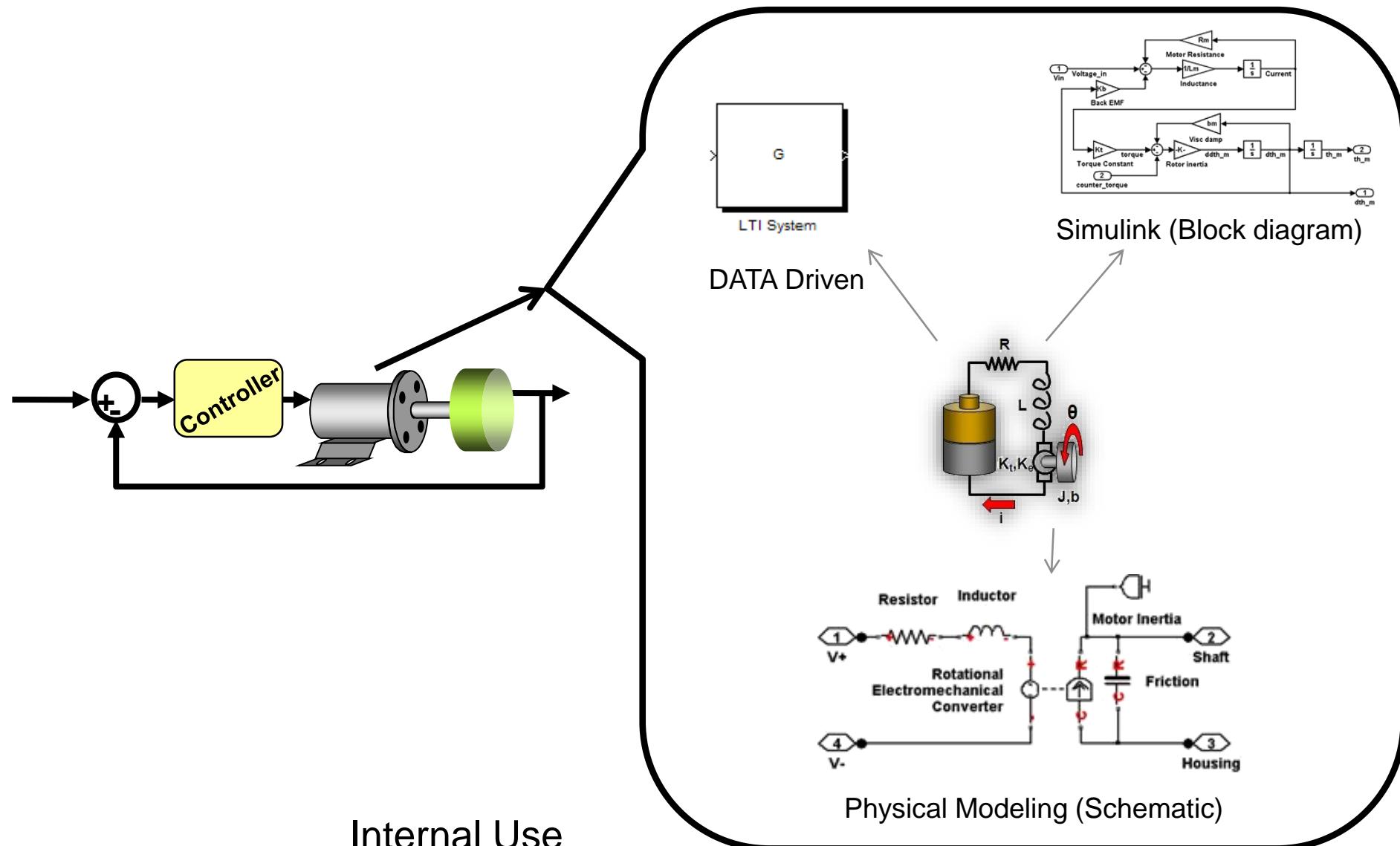
Prototype

Example

DEMO: pick and place robot



Different modeling approaches

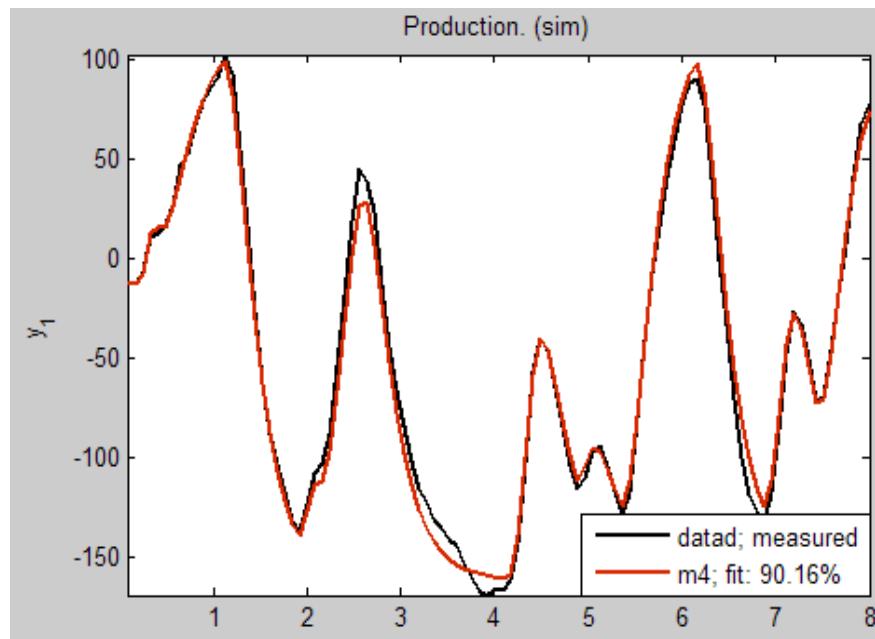


Demo: Creating Linear Models from Data

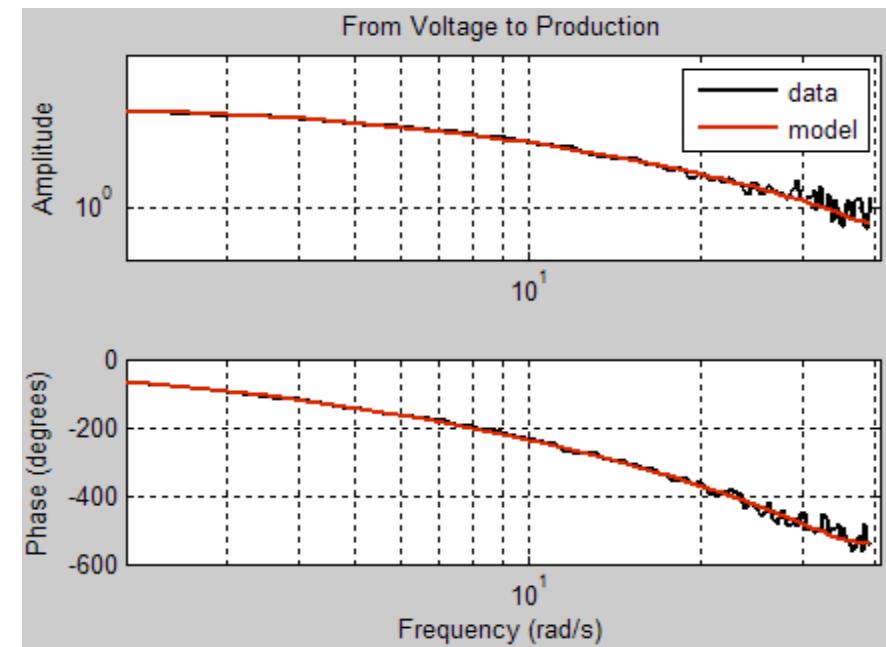
- Modeling process dynamics
- Using models in Simulink



Fit time domain data

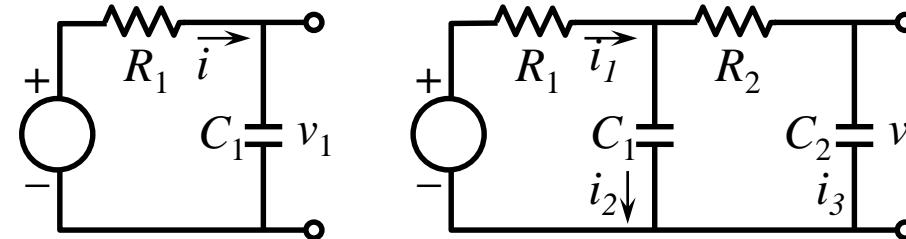


Fit frequency domain data

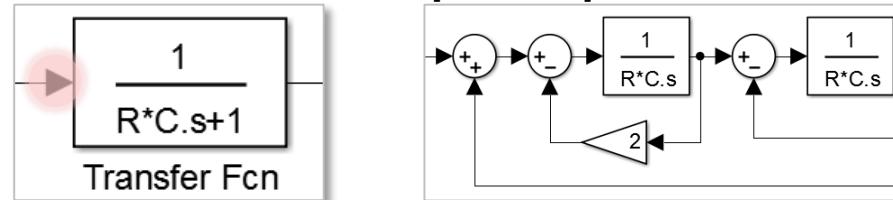


Physical Modeling Within Simulink

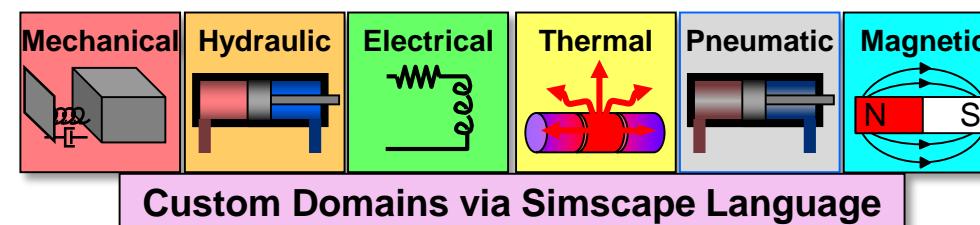
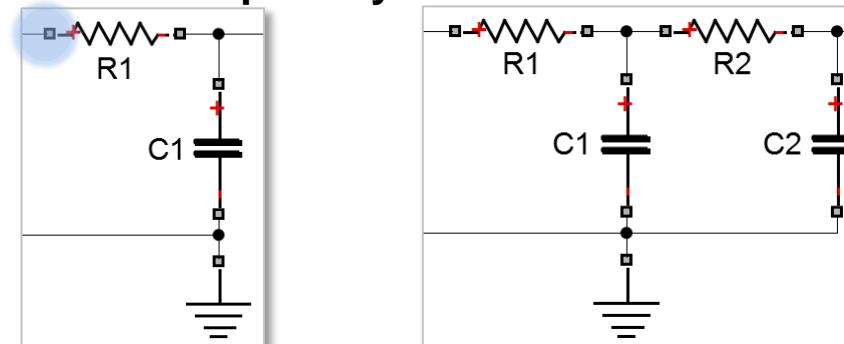
- Simulink is best known for signal-based modeling
 - Causal, or input/output
- Simscape enables bidirectional flow of power between components
- System level equations:
 - Formulated automatically
 - Solved simultaneously
 - Cover multiple domains



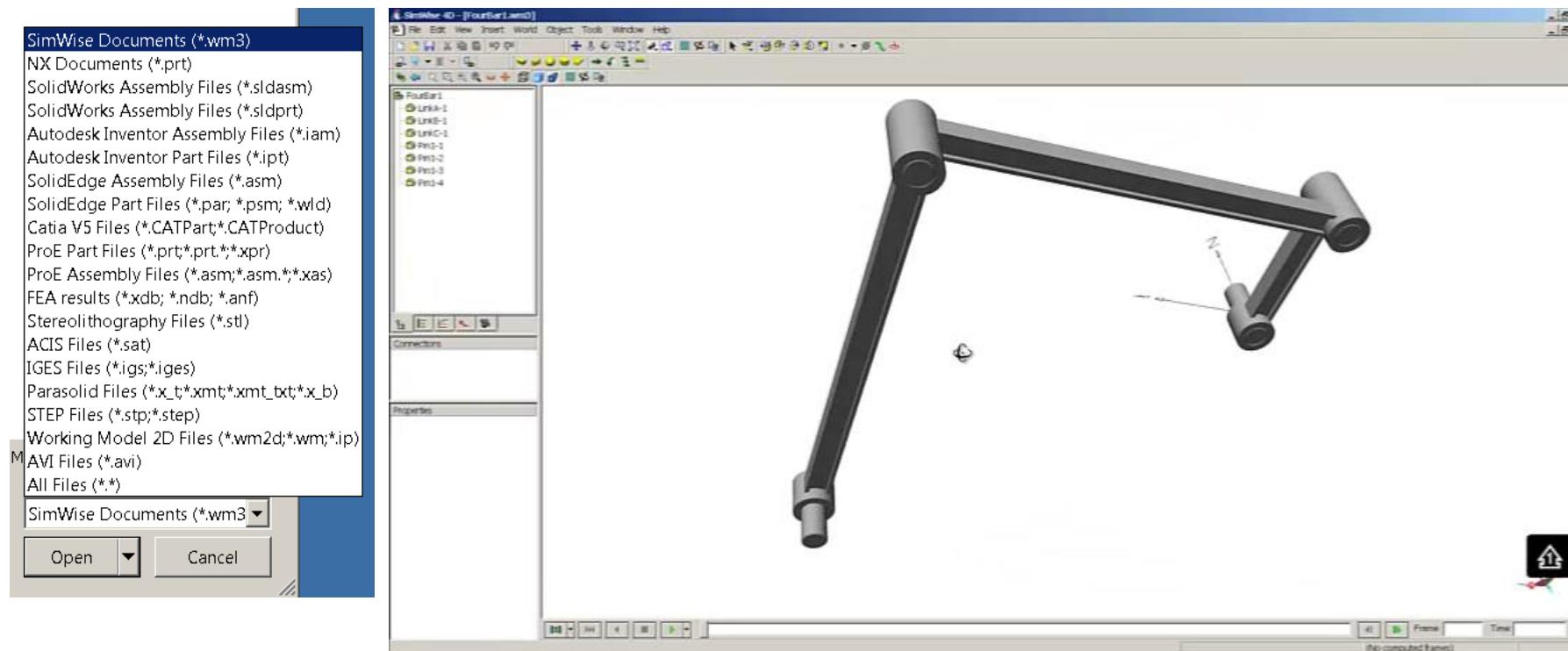
Simulink: Input/Output



Simscape: Physical Networks



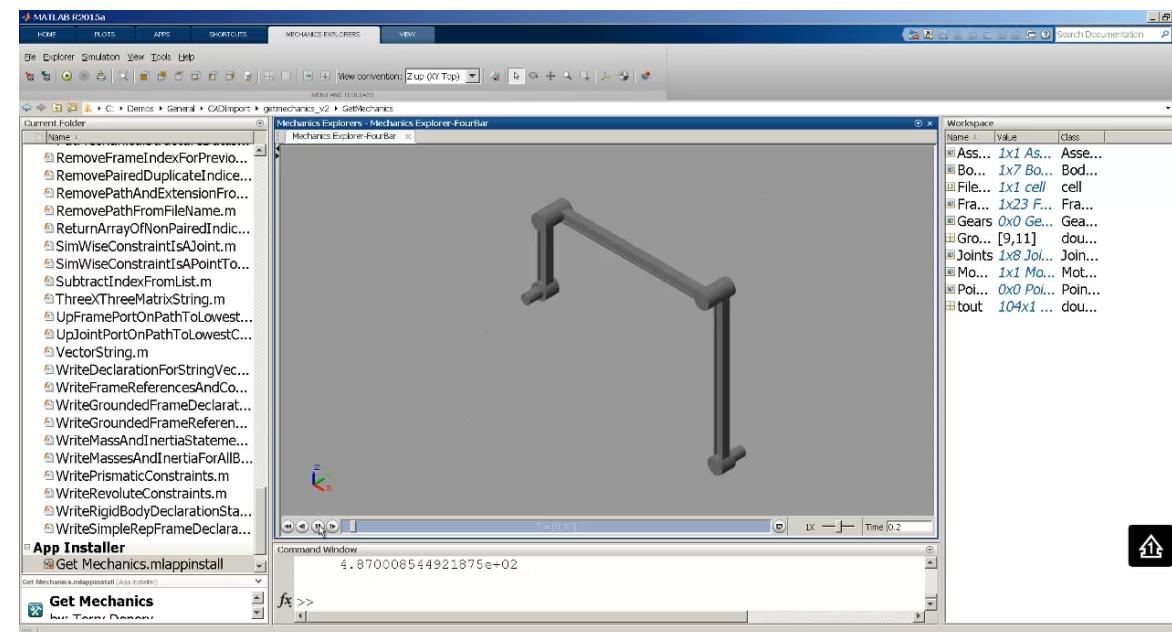
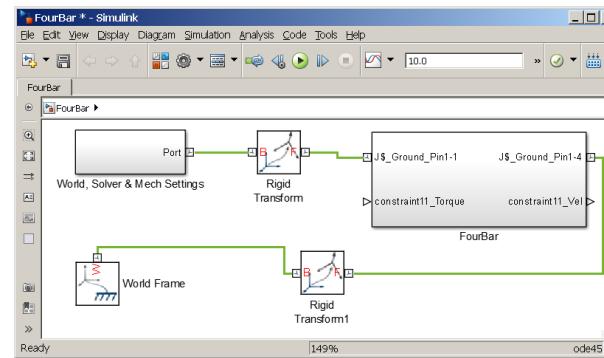
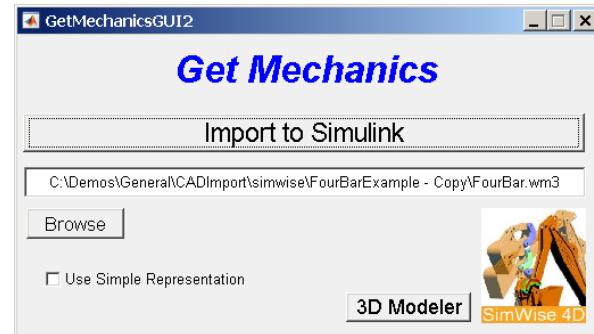
Importing CAD models



Open the CAD model in Simwise 4D

SimWise converts the CAD model into
SimMechanics convertible format (*.wm3)

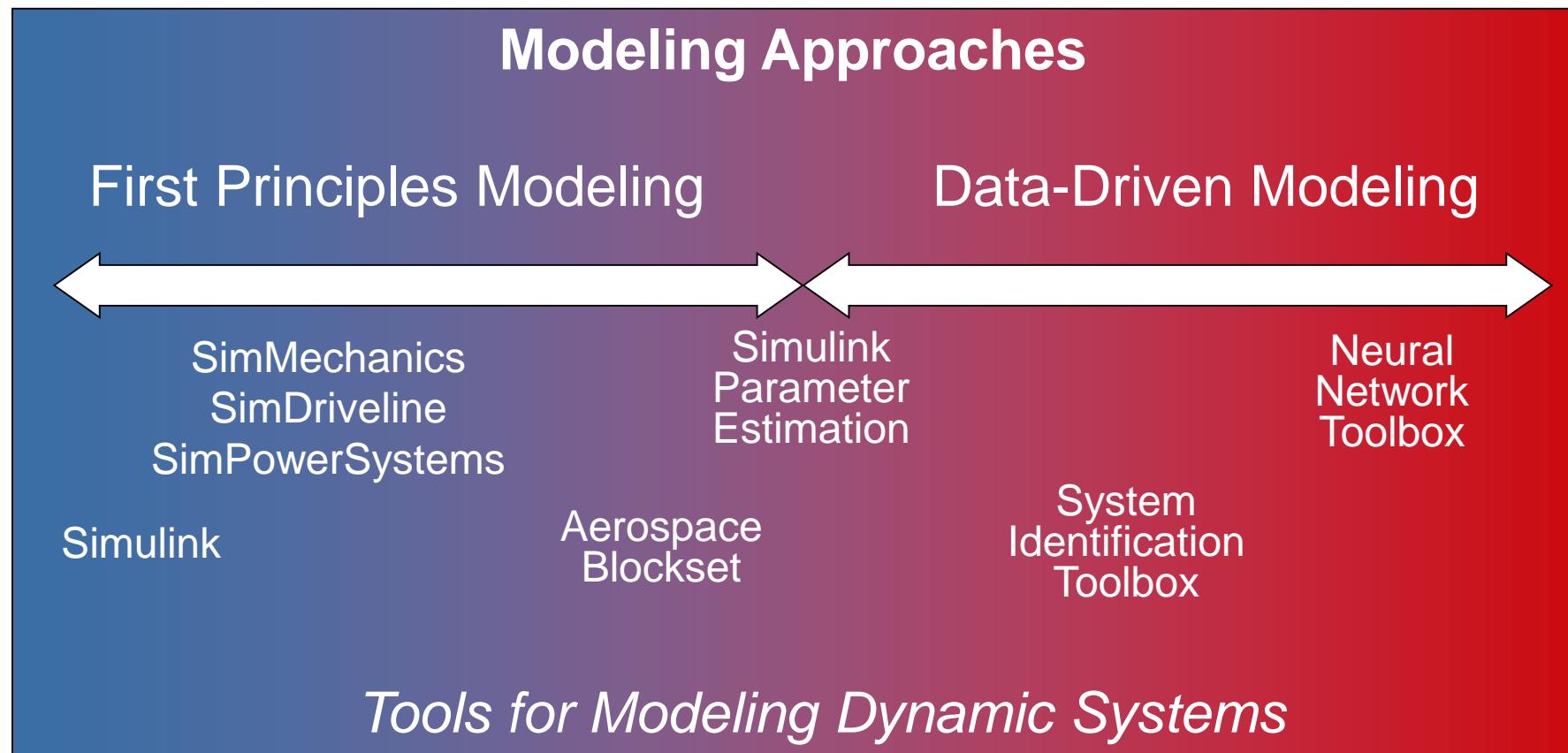
Automatically Create SimMechanics Models using GetMechanics App



GetMechanics App can import
SimWise *.wm3 file

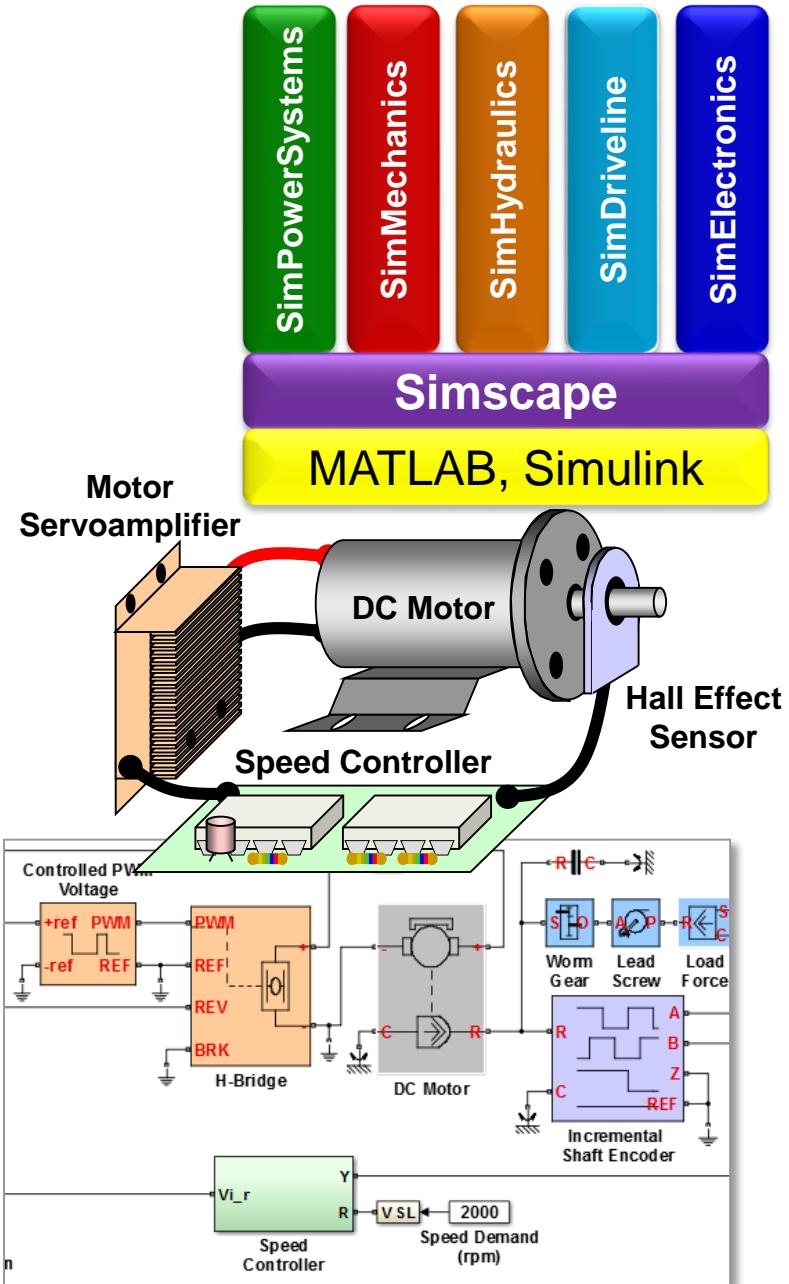
To get GetMechanics App
Contact MathWorks

Modeling Dynamic Systems in Simulink



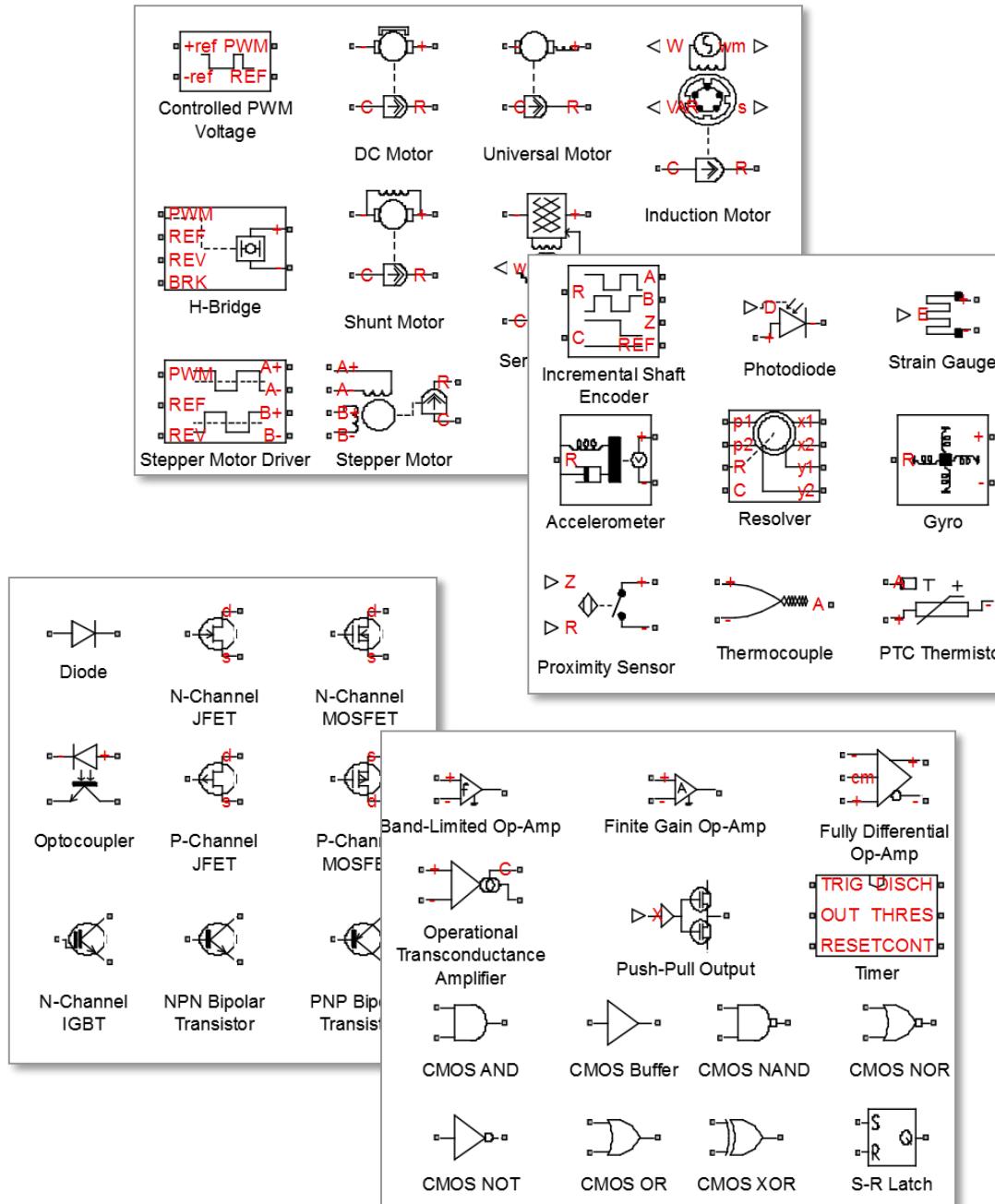
Introduction to SimElectronics

- Enables physical modeling (acausal) for electronic and mechatronic systems
- Provides sensor, actuator, and semiconductor models
- Supports algorithm and control system development in Simulink



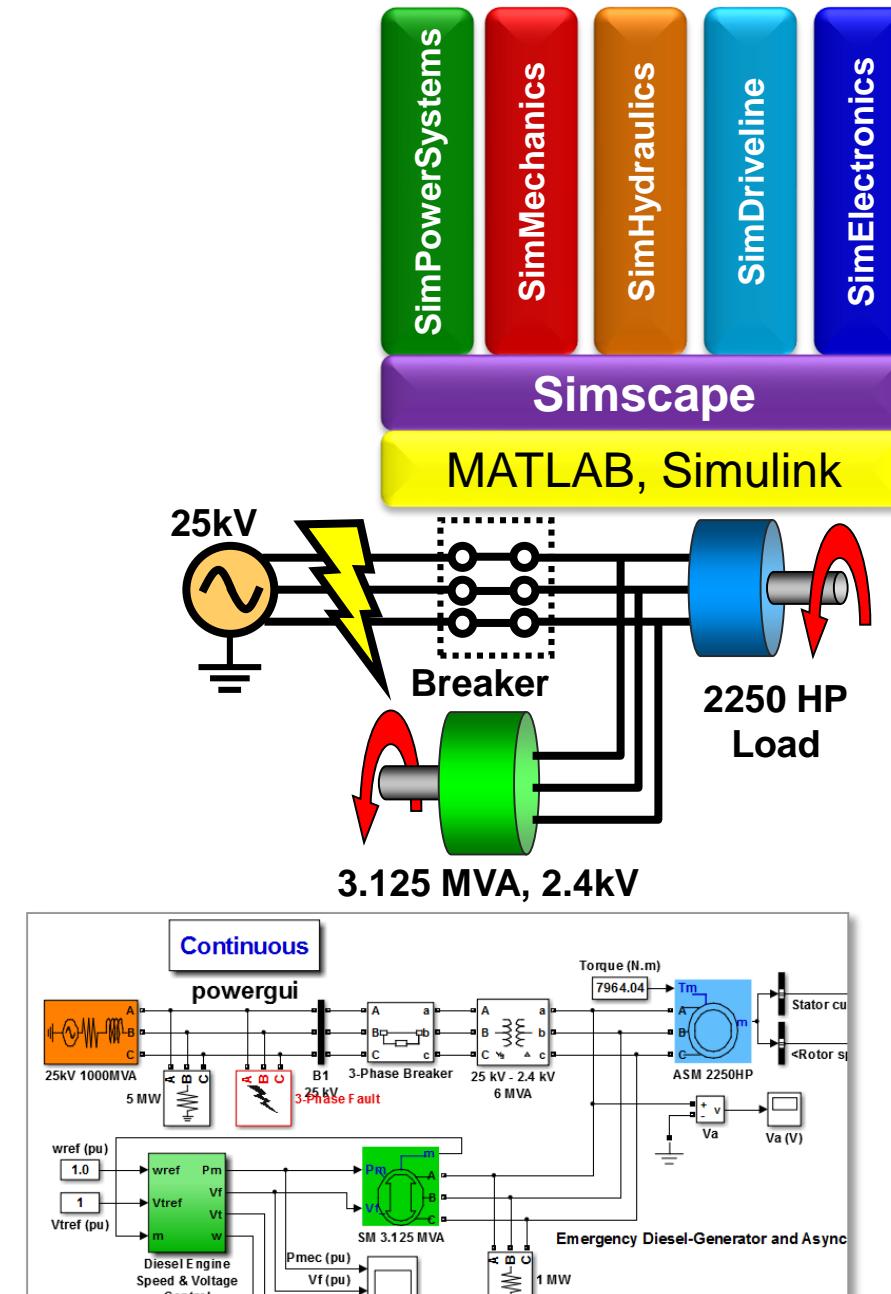
Extensive Component Libraries

- More than 90 component models
 - Actuators, drivers
 - Sensors
 - Semiconductors
 - Integrated circuits
 - Models look like schematics
 - Easy to read and interpret



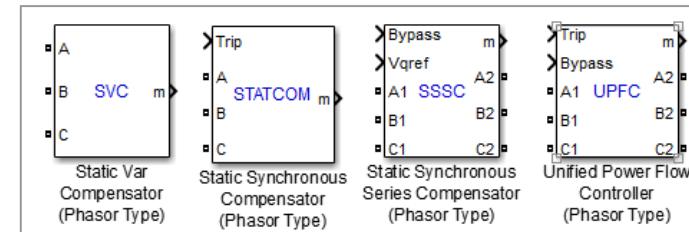
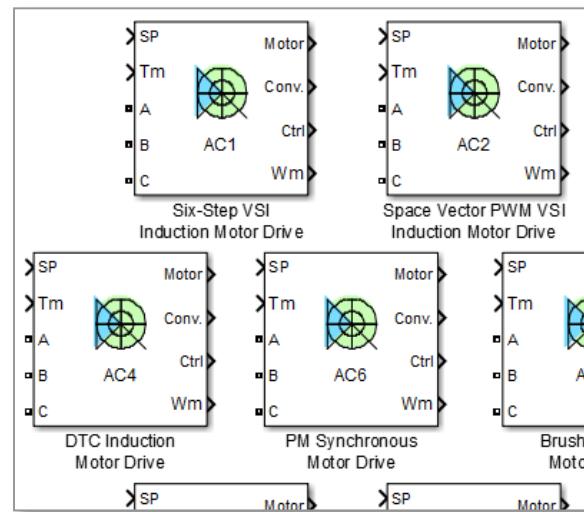
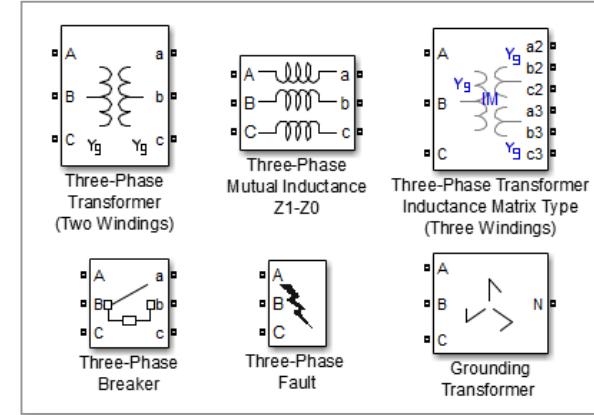
Introduction to SimPowerSystems

- Enables physical modeling (acausal) of electrical power systems and electric drives
- Electrical system topology represented by schematic circuit
- Used by electrical, system and control engineers to develop plant models and test control systems



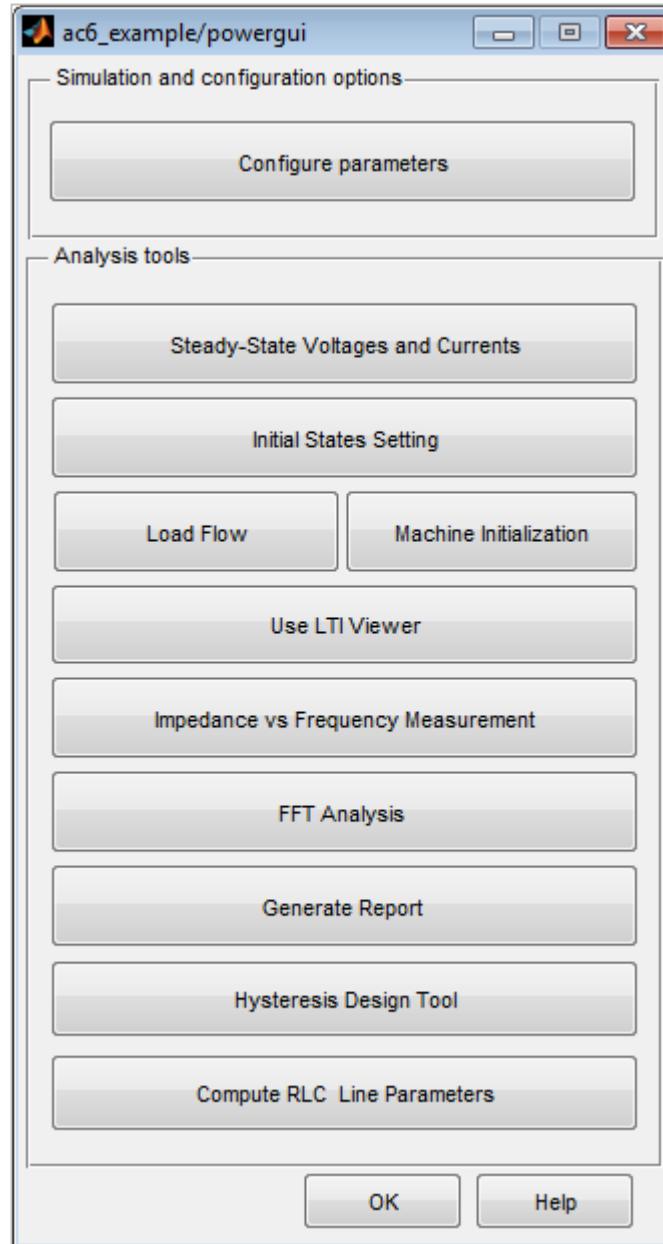
Quickly Build Electrical Systems

- Build models that look like an electrical schematic:
 - Three-phase components
 - Detailed electric drive models
 - Flexible AC Transmission Systems (FACTS)
- Parameterize model using MATLAB® variables
- Connect to Simulink with sources and sensors
- Save subsystems for reuse in other models or libraries

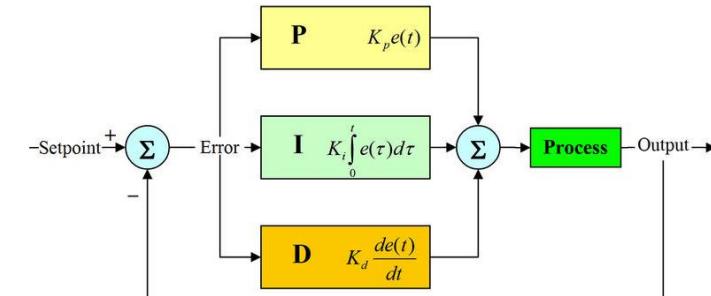
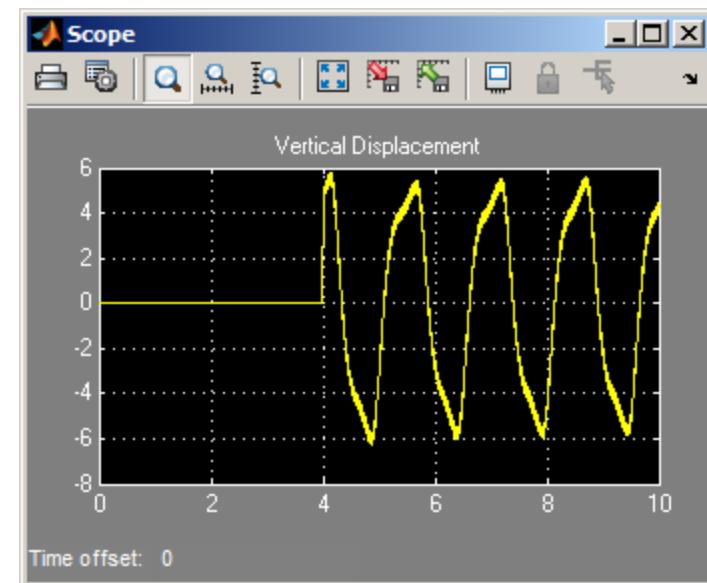
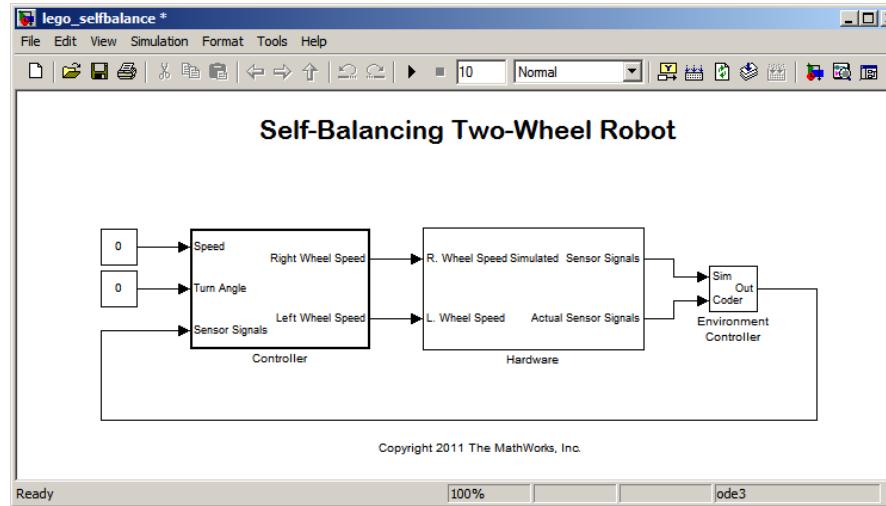


Electrical System Analysis

- Quick access to tools for common analysis tasks:
 - Display steady-state V and I
 - Display and modify initial states
 - Perform load flows
 - Display impedance measurements
 - FFT analysis
 - Report generation
- Multiple simulation modes
 - Discrete and phasor modes enable you to speed up simulations



Modeling the Controller



PID

Know your plant/system -
Linearization

Design the controller with linear
plant model

Test controller with non-linear
plant in closed-loop

Design state-logic and
supervisory logic

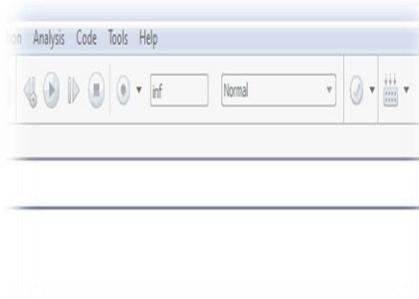
Test the controller in real time

Simulink

Run on target hardware

Run Simulink models on low-cost target hardware

- With a click, your model runs on target hardware
- Supported target hardware:
 - new – R2013a: Raspberry Pi®
 - new – R2013a: Gumstix® Overo®
 - R2012b: PandaBoard
 - R2012a: Arduino®, LEGO® MINDSTORMS® NXT and BeagleBoard



BeagleBoard



PandaBoard



Arduino®



LEGO® MINDSTORMS® NXT



Gumstix® Overo®



Raspberry Pi®



Machine Learning & Data Analytics

Dhirendra Singh

Application Engineer

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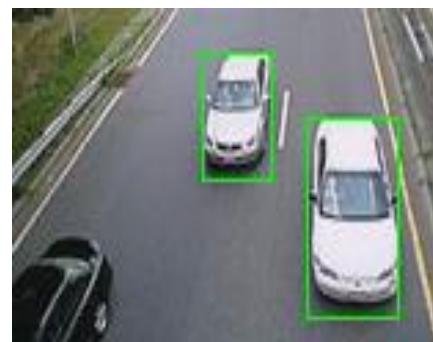
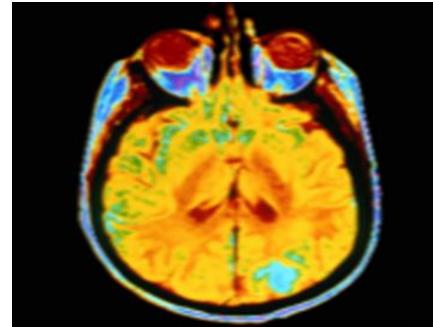
Deepak Sharma

Sales Manager

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Machine Learning is Everywhere

- Image Recognition
- Speech Recognition
- Stock Prediction
- Medical Diagnosis
- Data Analytics
- Robotics
- and more...

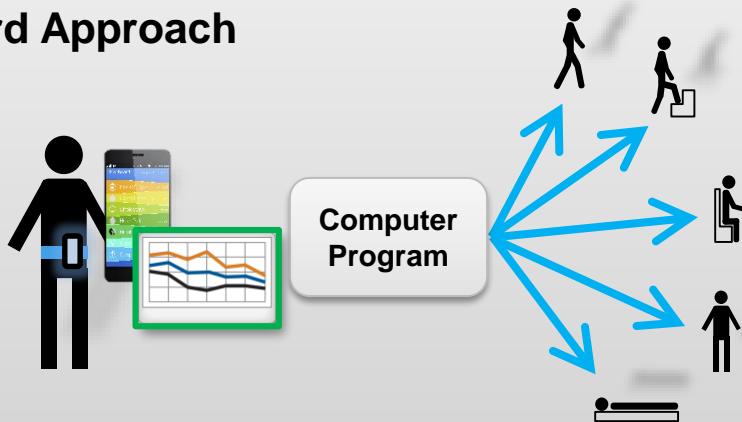


Machine Learning

Machine learning uses **data** and produces a **program** to perform a **task**

Task: Human Activity Detection

Standard Approach



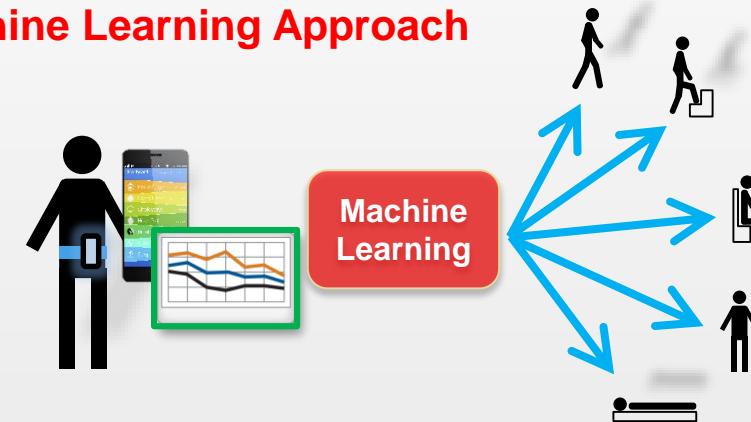
Hand Written Program

```
If X_acc > 0.5  
then "SITTING"  
If Y_acc < 4 and Z_acc > 5  
then "STANDING"  
...
```

Formula or Equation

$$Y_{activity} = \beta_1 X_{acc} + \beta_2 Y_{acc} + \beta_3 Z_{acc} + \dots$$

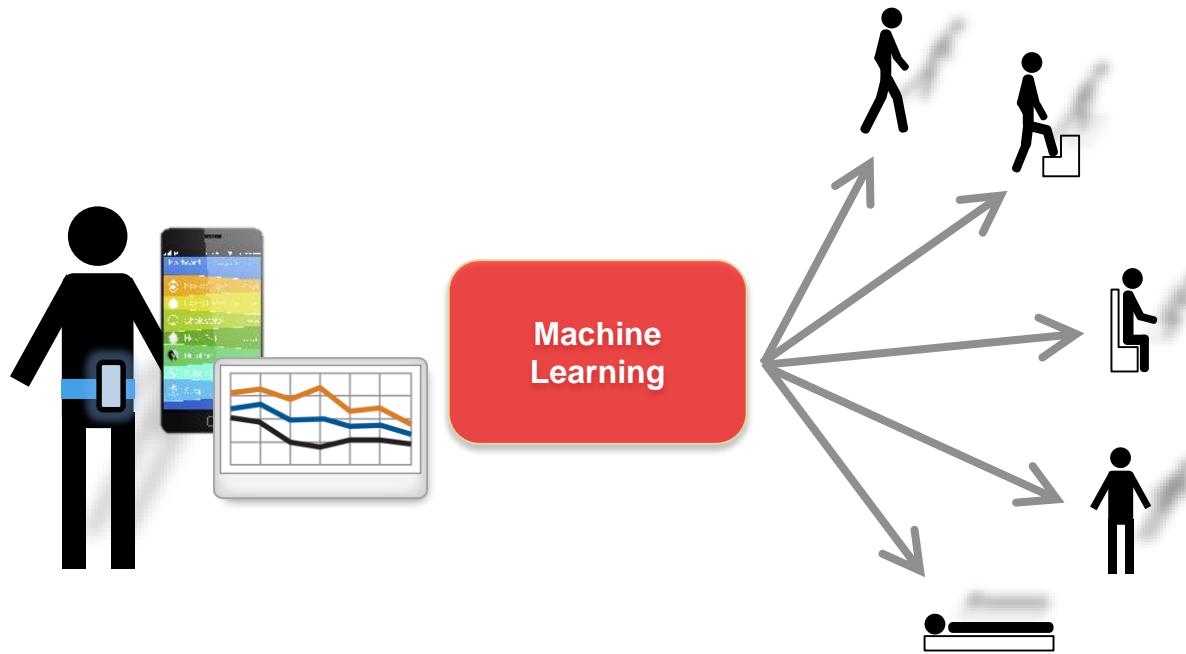
Machine Learning Approach



model: Inputs → Outputs

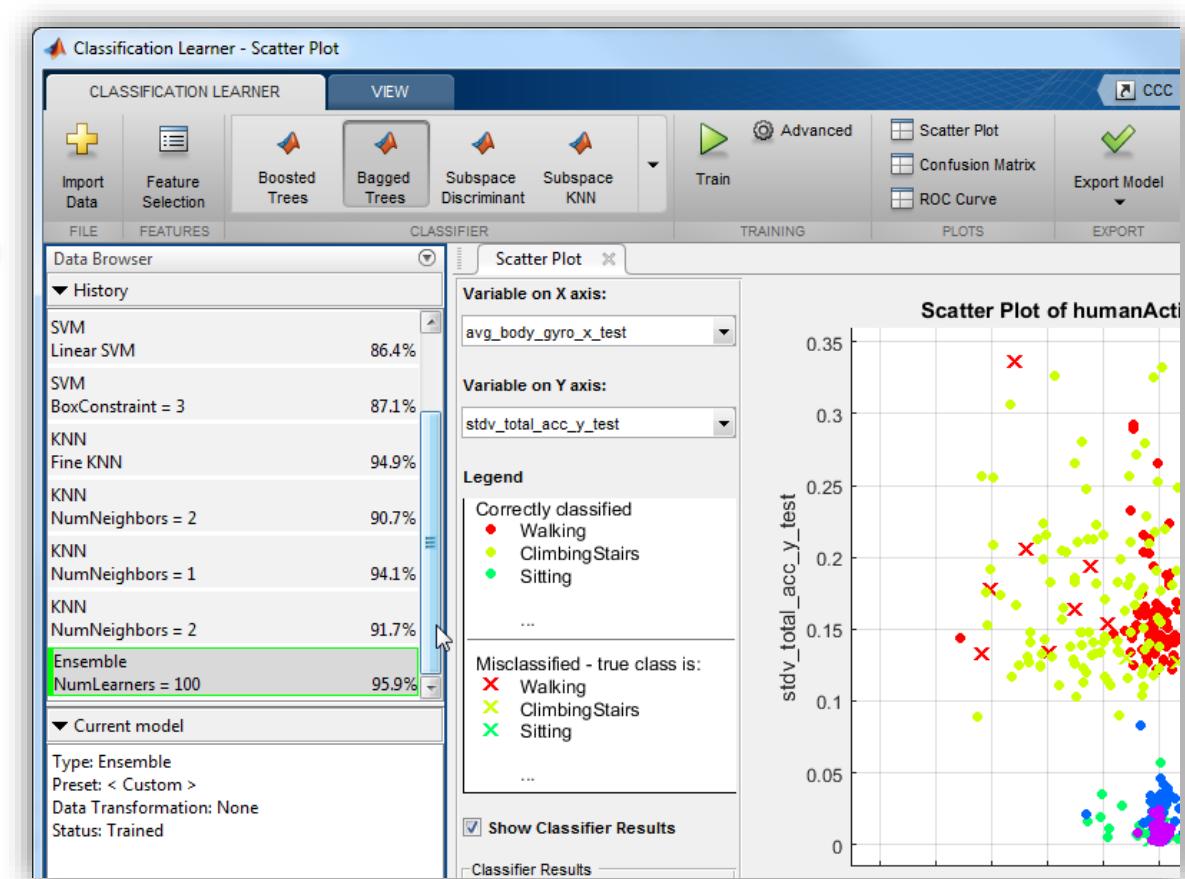
model = *Machine Learning* (*sensor_data, activity*)

Example: Human Activity Learning Using Mobile Phone Data



Data:

- 3-axial Accelerometer data
- 3-axial Gyroscope data



Example 1: Human Activity Learning Using Mobile Phone Data

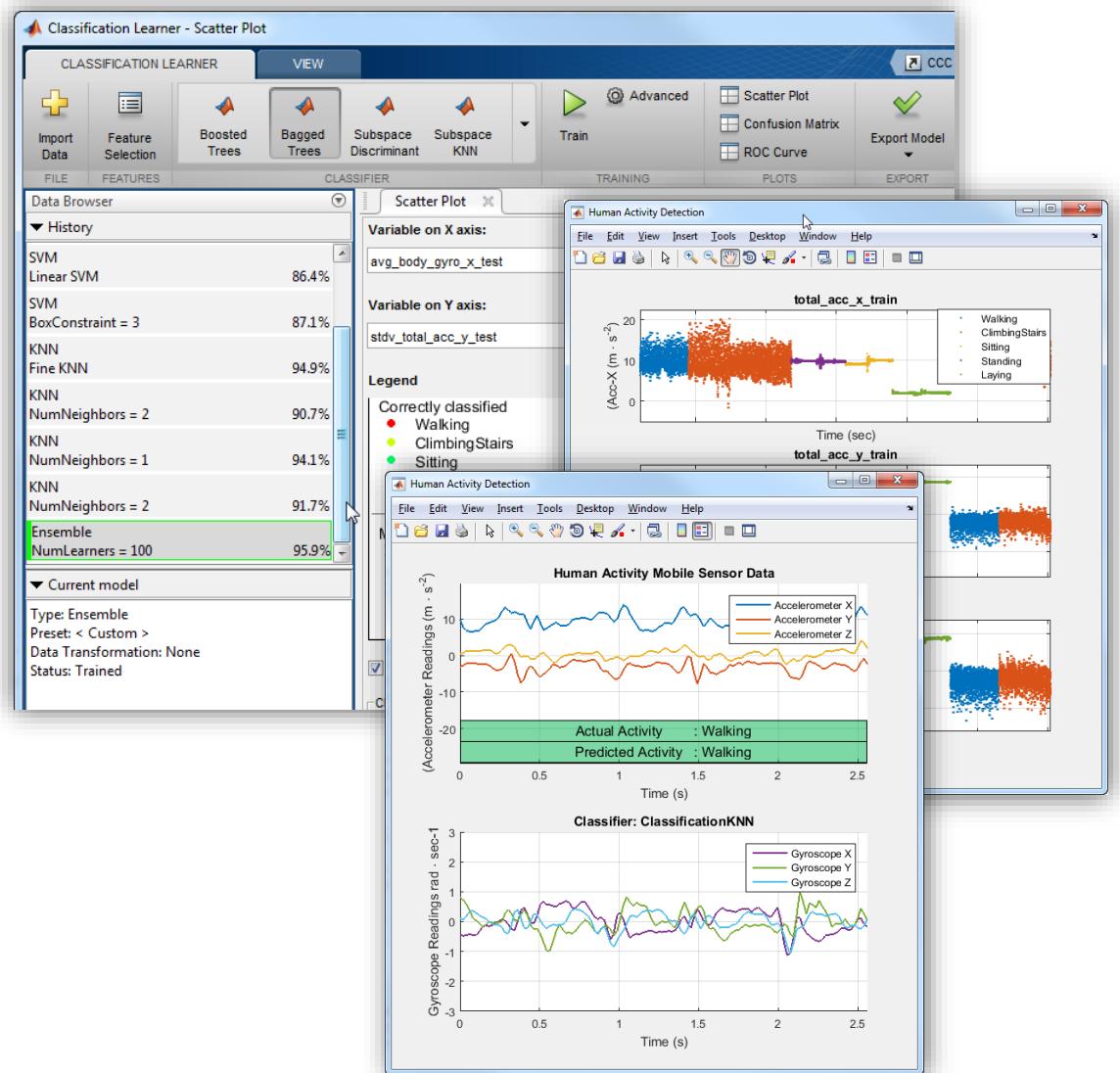
Objective: Train a classifier to classify human activity from sensor data

Data:

Predictors	3-axis Accelerometer and Gyroscope data
Response	Activity: 

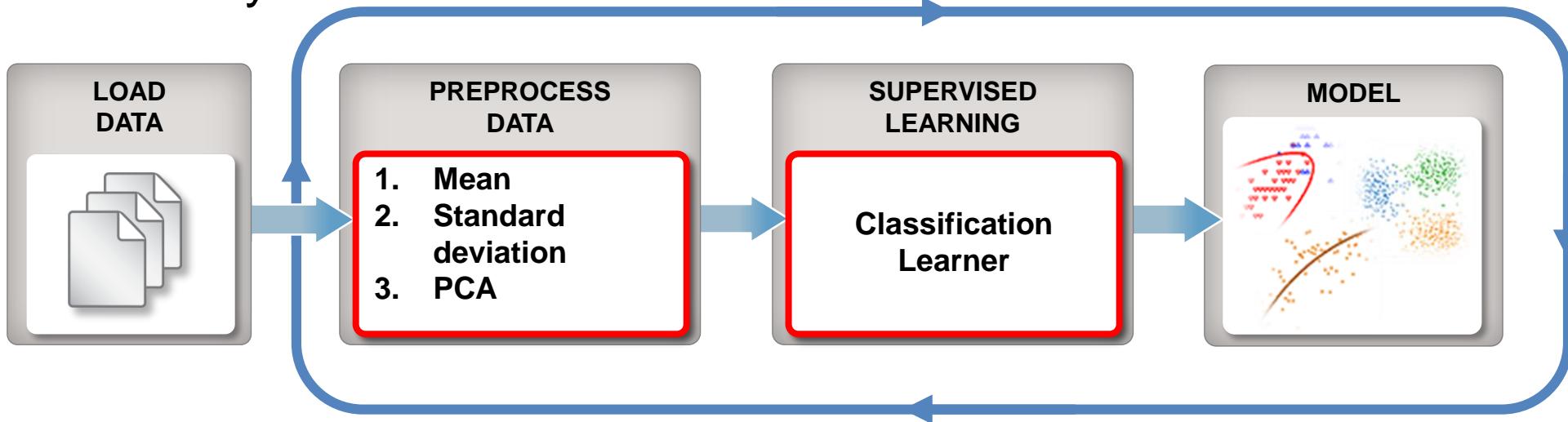
Approach:

- Extract features from raw sensor signals
- Train and compare classifiers
- Test results on new sensor data

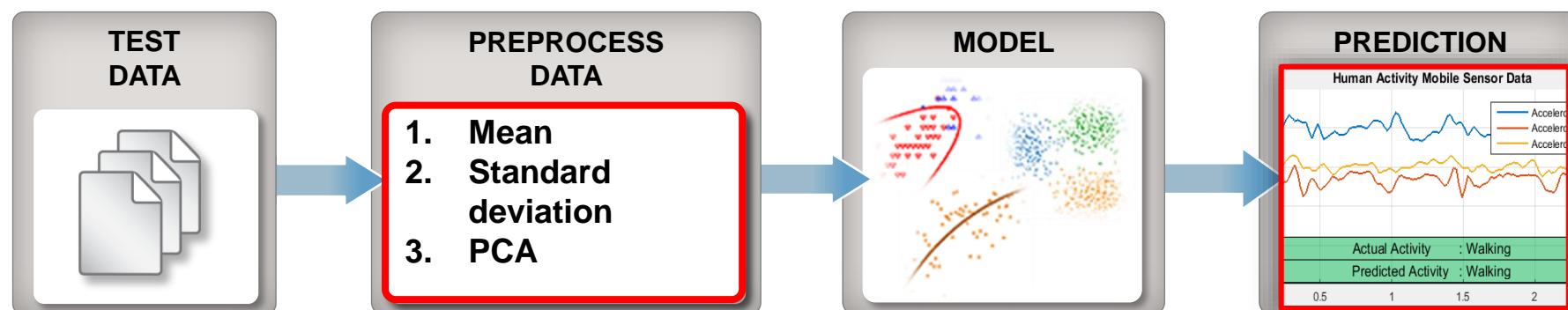


Machine Learning Workflow for Example 1

Train: Iterate till you find the best model



Predict: Integrate trained models into applications



Example 2: Real-time Car Identification Using Images

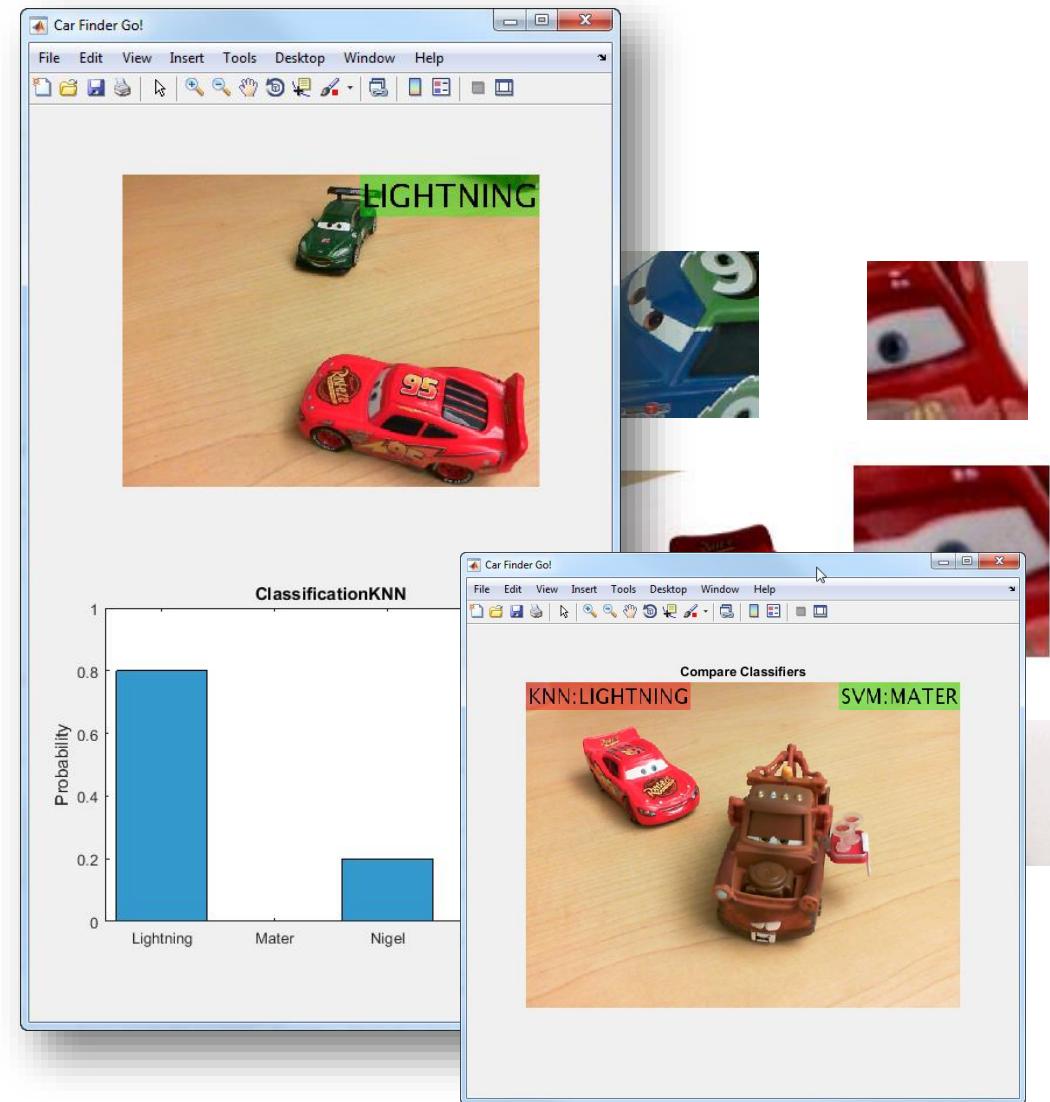
Objective: Train a classifier to identify car type from a webcam video

Data:

Predictors	Several images of cars: 
Response	NIGEL, LIGHTNING, SANDDUNE, MATER

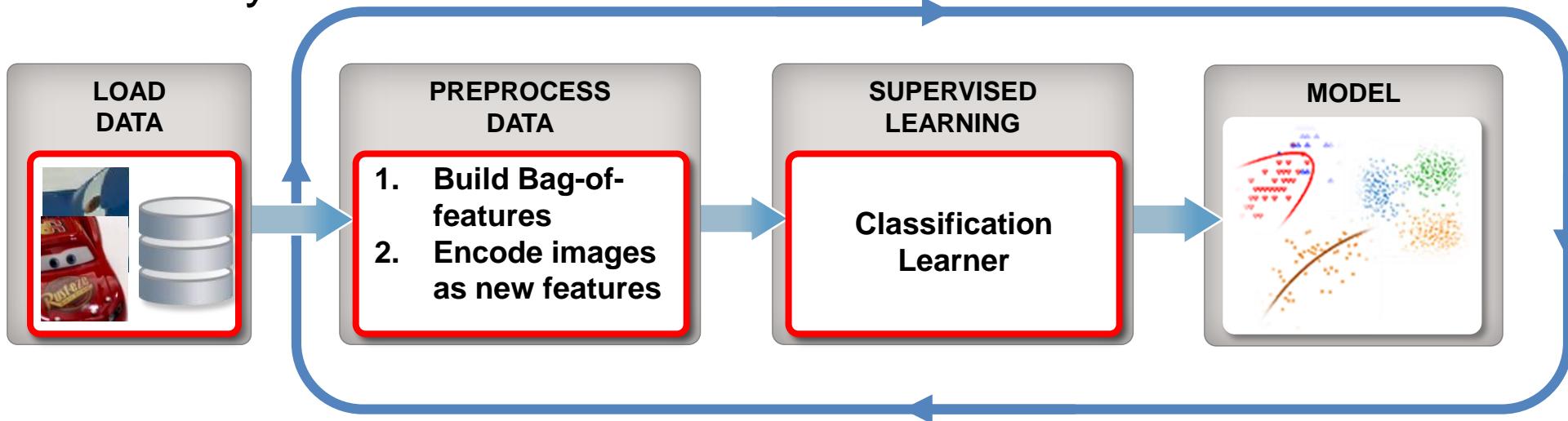
Approach:

- Extract features using Bag-of-words
- Train and compare classifiers
- Classify streaming video from a webcam

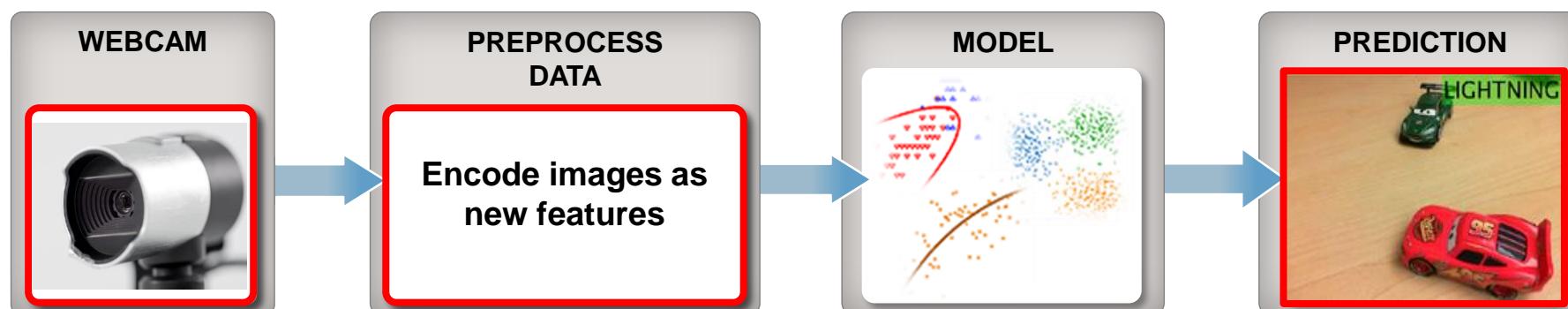


Machine Learning Workflow for Example 2

Train: Iterate till you find the best model

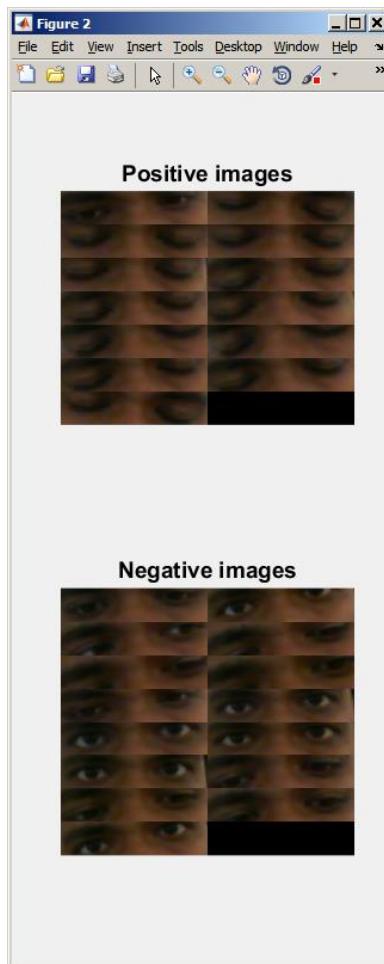


Predict: Integrate trained models into applications

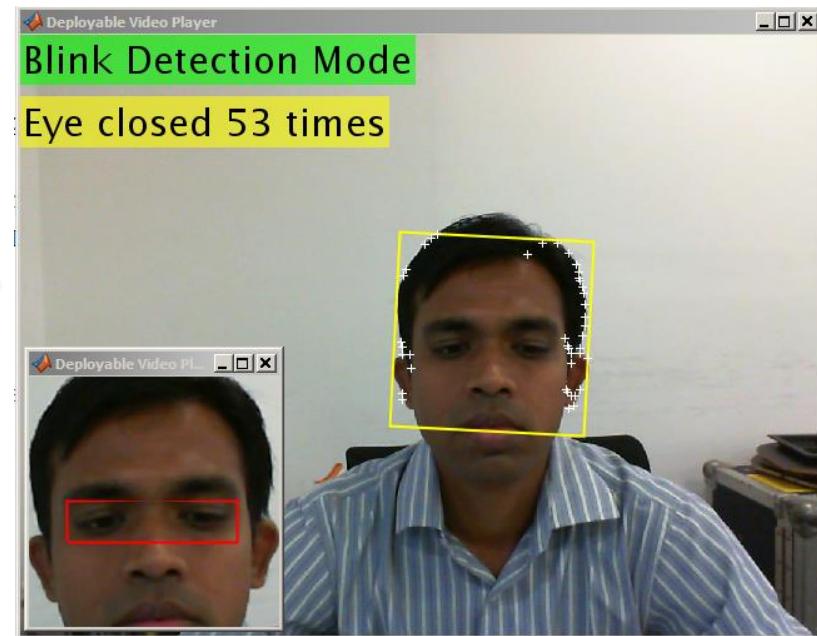


Detect Eye Blinks and Count Them

- Detect eye blinks using the KLT algorithm, HOG features and a binary SVM classifier

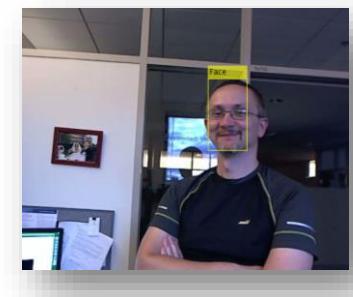


Training

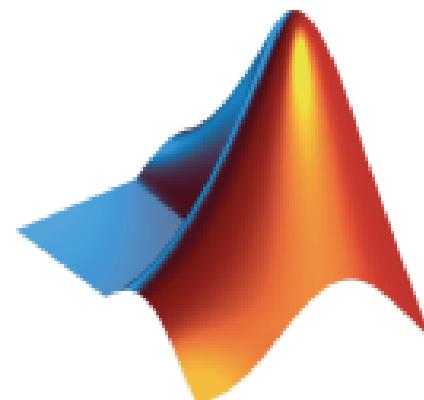


Key Takeaways

- Consider Machine Learning when:
 - Hand written rules and equations are too complex
 - *Face recognition, speech recognition, recognizing patterns*
 - Rules of a task are constantly changing
 - *Fraud detection from transactions, anomaly in sensor data*
 - Nature of the data changes and the program needs to adapt
 - *Automated trading, energy demand forecasting, predicting shopping trends*



- MATLAB for Machine Learning



Email me if you have further questions

Additional Resources

Documentation:

[mathworks.com/machine-learning](#)

Documentation

CONTENTS Close

All Products

Statistics and Machine Learning Toolbox

Exploratory Data Analysis

Probability Distributions

Hypothesis Tests

Regression and ANOVA

Machine Learning

- Supervised Learning
- Unsupervised Learning
- Ensemble Learning
- Multivariate Data Analysis
- Industrial Statistics
- Speed Up Statistical Computations

Machine Learning

Supervised, unsupervised, and ensemble learning

R2015a

The aim of machine learning is to build a model that makes decisions based on evidence in the presence of uncertainty. As adaptive algorithms identify patterns in data, a computer "learns" from the observations. When exposed to more observations, the computer improves its decision-making performance.

In supervised learning, each observation has a corresponding response or label. Classification models learn to predict a discrete class given new predictor data, and regression models learn to predict continuous responses. Applications include spam filters, stock price forecasts, advertisement recommendation systems, and image and speech recognition. The Statistics and Machine Learning Toolbox™ supervised learning functionalities comprise a stream-lined, object framework to train a variety of algorithms efficiently, assess models, and predict responses.

In unsupervised learning, observations are unlabeled. The goal is to learn the structure of the data, such as revealing natural clusters or variable correlations. Applications include pattern recognition in images and gene expression profiles, identification of crime hot spots, and microarray data reduction. The Statistics and Machine Learning Toolbox unsupervised learning functionalities include hierarchical and k-means clustering, and principal component analysis.

Machine Learning Basics

Steps in Supervised Learning	What Are Linear Regression Models?
Characteristics of Classification Algorithms	Introduction to Cluster Analysis
What Are Classification Trees and Regression Trees?	Introduction to Feature Selection

Supervised Learning
Regression, support vector machines, parametric and nonparametric classification, decision trees

Unsupervised Learning
Clustering, Gaussian mixture models, hidden Markov models

Ensemble Learning
Ensembles for boosting, bagging, or random subspace

Was this topic helpful?

[mathworks.com/machine-learning](#)

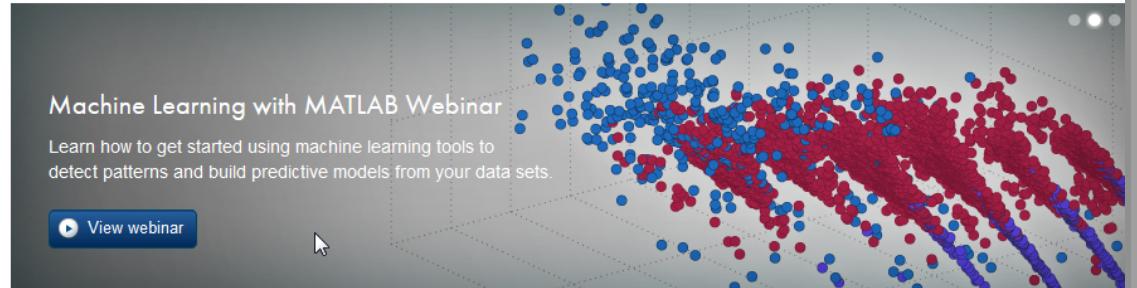
Machine Learning with MATLAB

Contact sales Trial software

Machine Learning with MATLAB Webinar

Learn how to get started using machine learning tools to detect patterns and build predictive models from your data sets.

[View webinar](#)



Machine learning algorithms use computational methods to "learn" information directly from data without assuming a predetermined equation as a model. They can adaptively improve their performance as you increase the number of samples available for learning.

Machine learning algorithms are used in applications such as **computational finance** (credit scoring and algorithmic trading), **computational biology** (tumor detection, drug discovery, and DNA sequencing), **energy production** (price and load forecasting), natural language processing speech and image recognition, and advertising and recommendation systems.

Machine learning is often used in **big data** applications, which have large datasets with many predictors (features) and are too complex for a simple parametric model. Examples of big data applications include **forecasting electricity load** with a neural network, or bond rating classification for **credit risk** using an ensemble of decision trees.

Classification

Build models to classify data into different categories.



Algorithms: support vector machine (SVM), boosted and bagged decision trees,

Regression

Build models to predict continuous data.



Algorithms: linear model, nonlinear model, regularization, stepwise regression, boosted

Clustering

Find natural groupings and patterns in data.



Algorithms: k-means, hierarchical clustering, Gaussian mixture models, hidden

Thank You