ThingSpeak and the Internet of Things (IoT)

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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

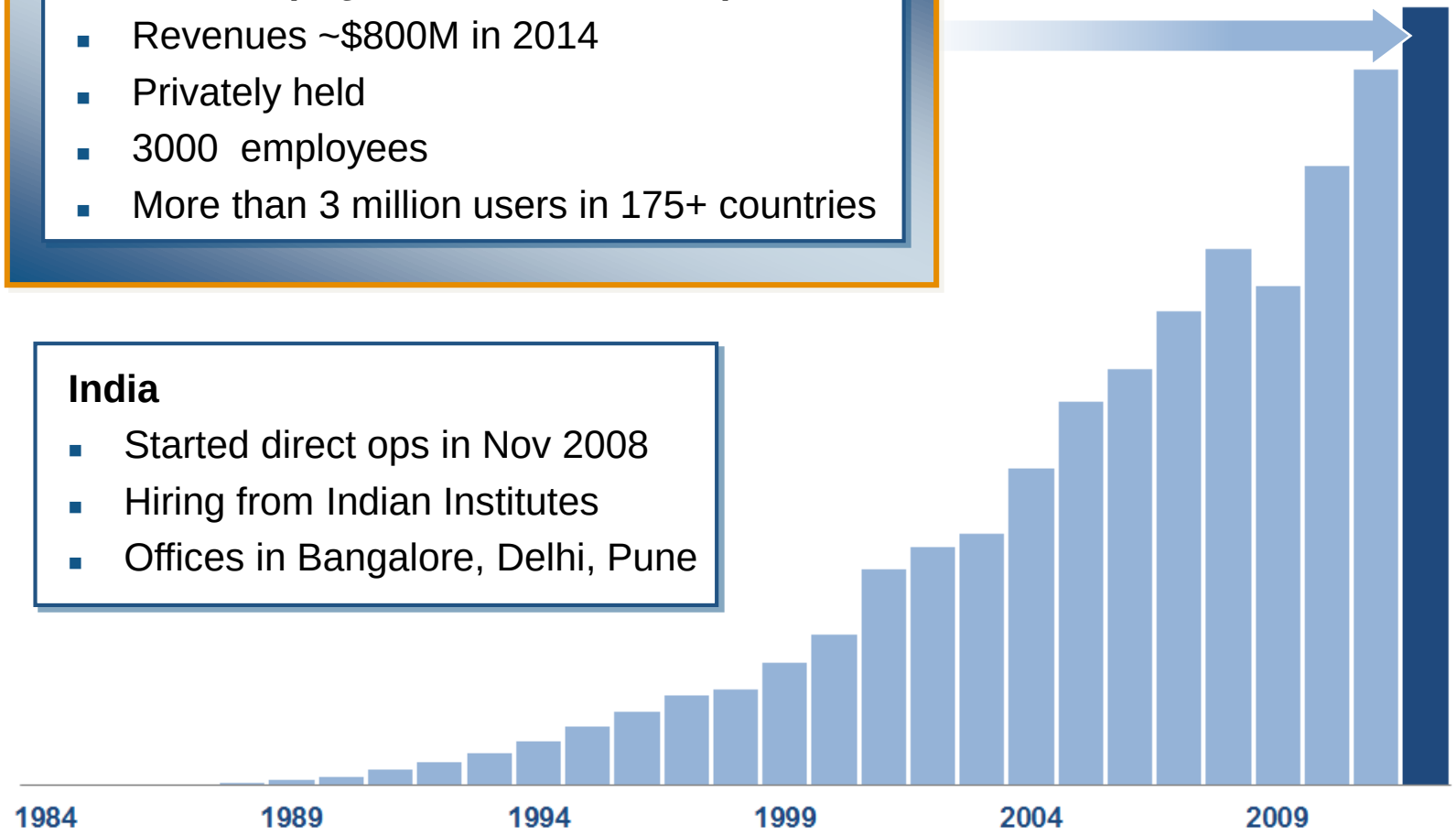
MathWorks Today

Worldwide (HQ Massachusetts, US)

- Revenues ~$800M in 2014
- Privately held
- 3000 employees
- More than 3 million users in 175+ countries

India

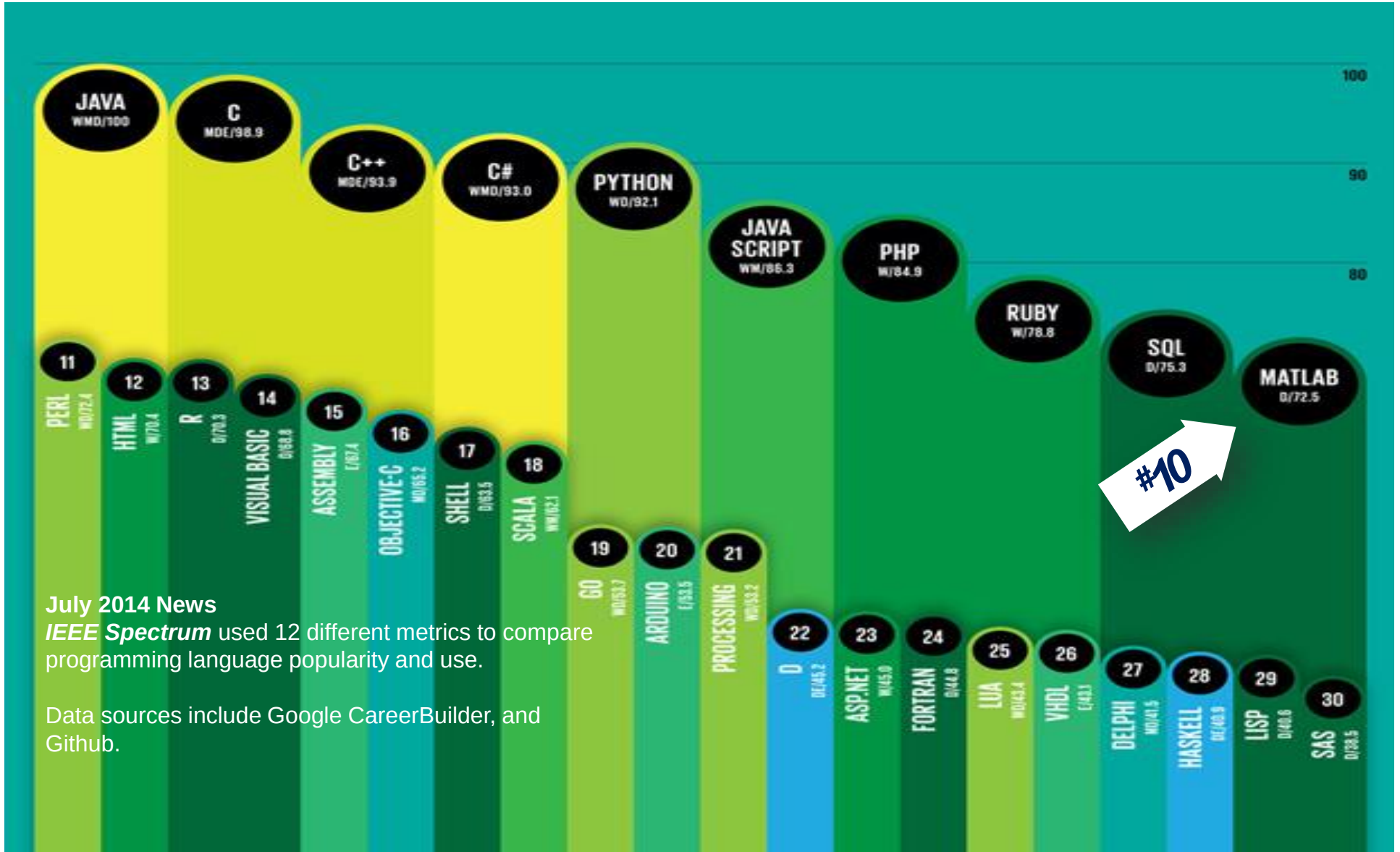
- Started direct ops in Nov 2008
- Hiring from Indian Institutes
- Offices in Bangalore, Delhi, Pune



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



July 2014 News
IEEE Spectrum used 12 different metrics to compare programming language popularity and use.

Data sources include Google CareerBuilder, and Github.

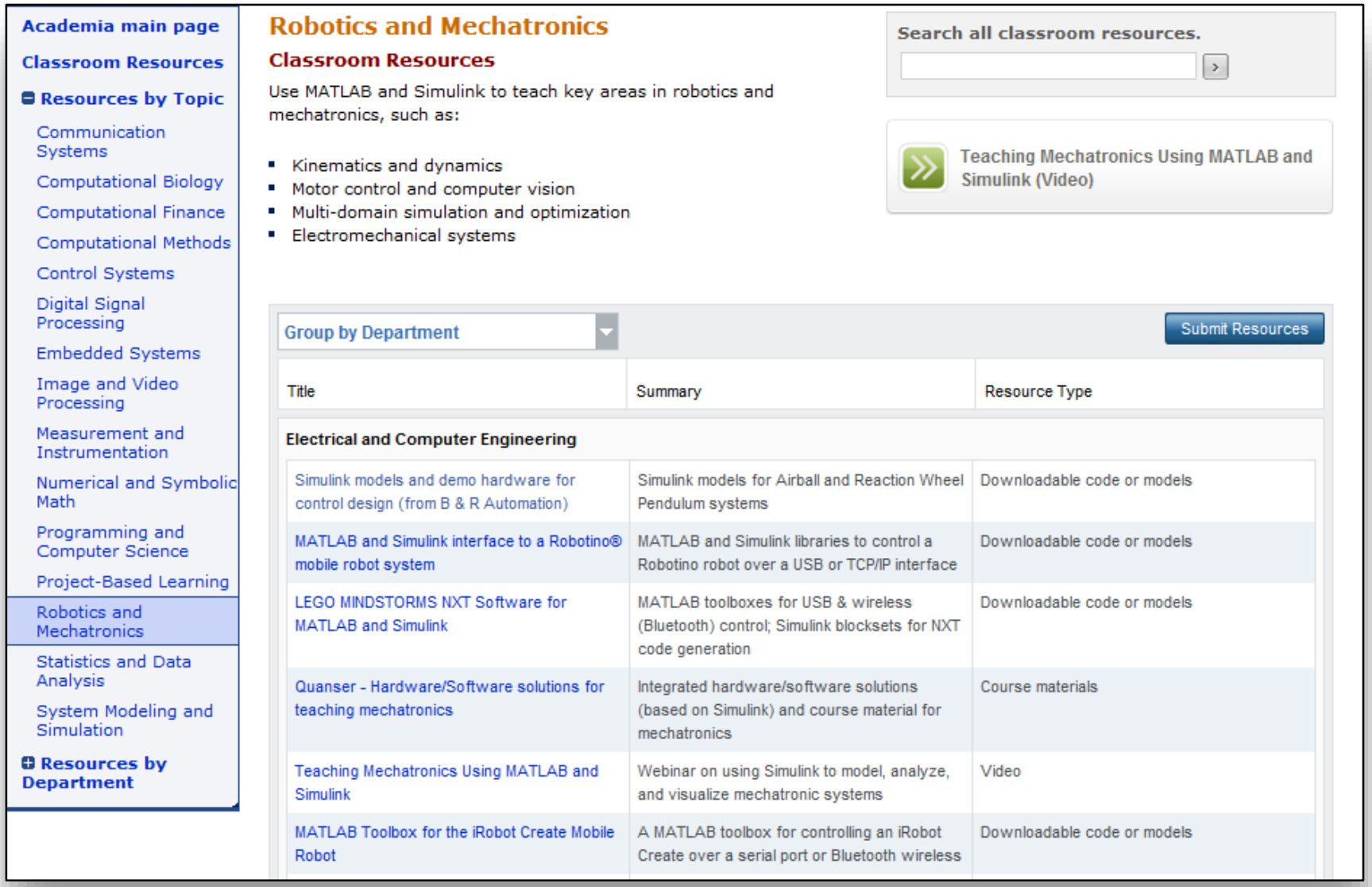
Supporting Innovation

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

Based on Feb-March 2009 data

Classroom Resources at mathworks.in



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

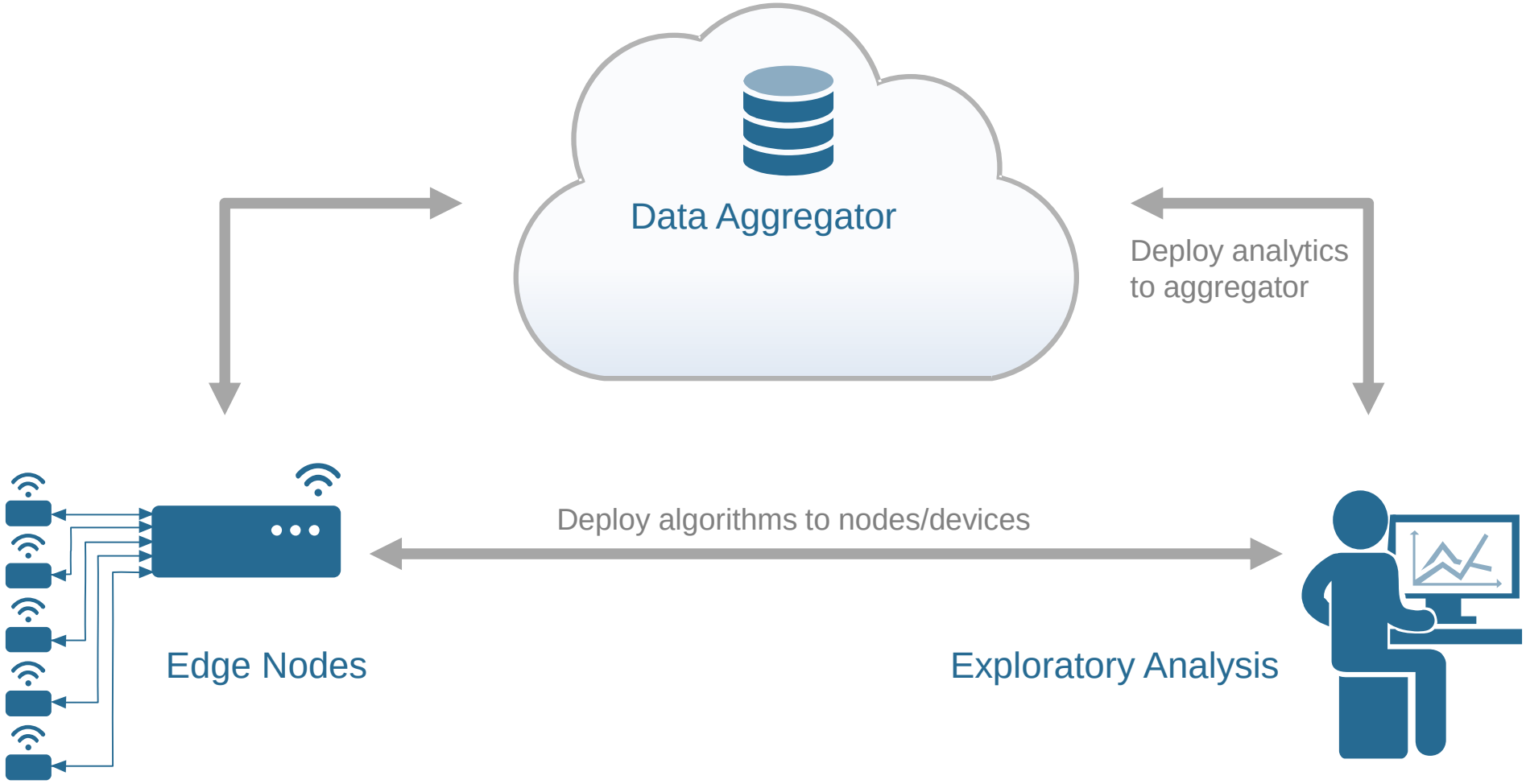
Areas:

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

Agenda

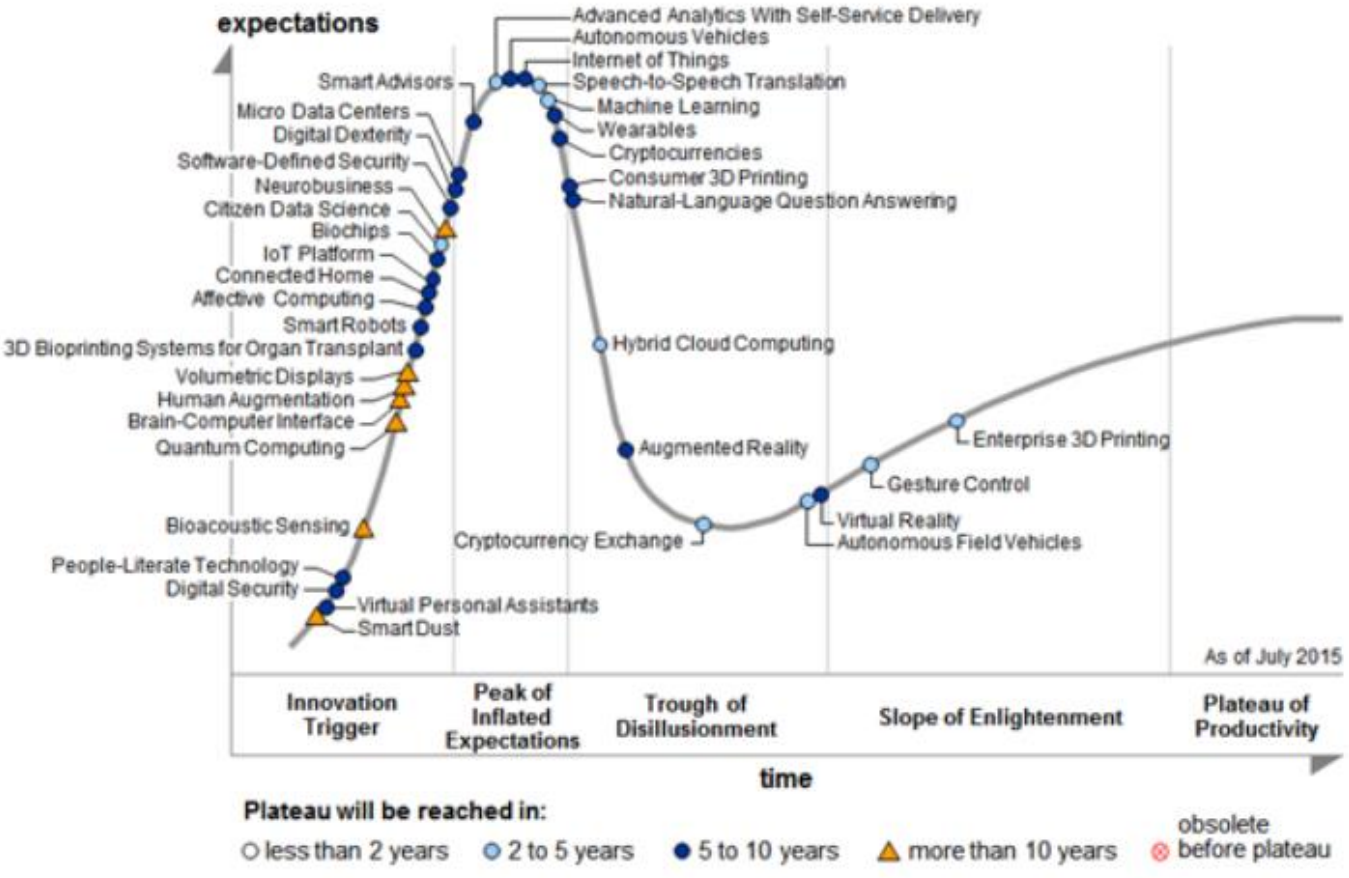
- What is IoT?
- Market Drivers and Challenges
- Our Response
- Introduction to ThingSpeak
  - Examples
- Other IoT examples using MW tools
- MATLAB and Simulink Capabilities for IoT
- Summary

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.

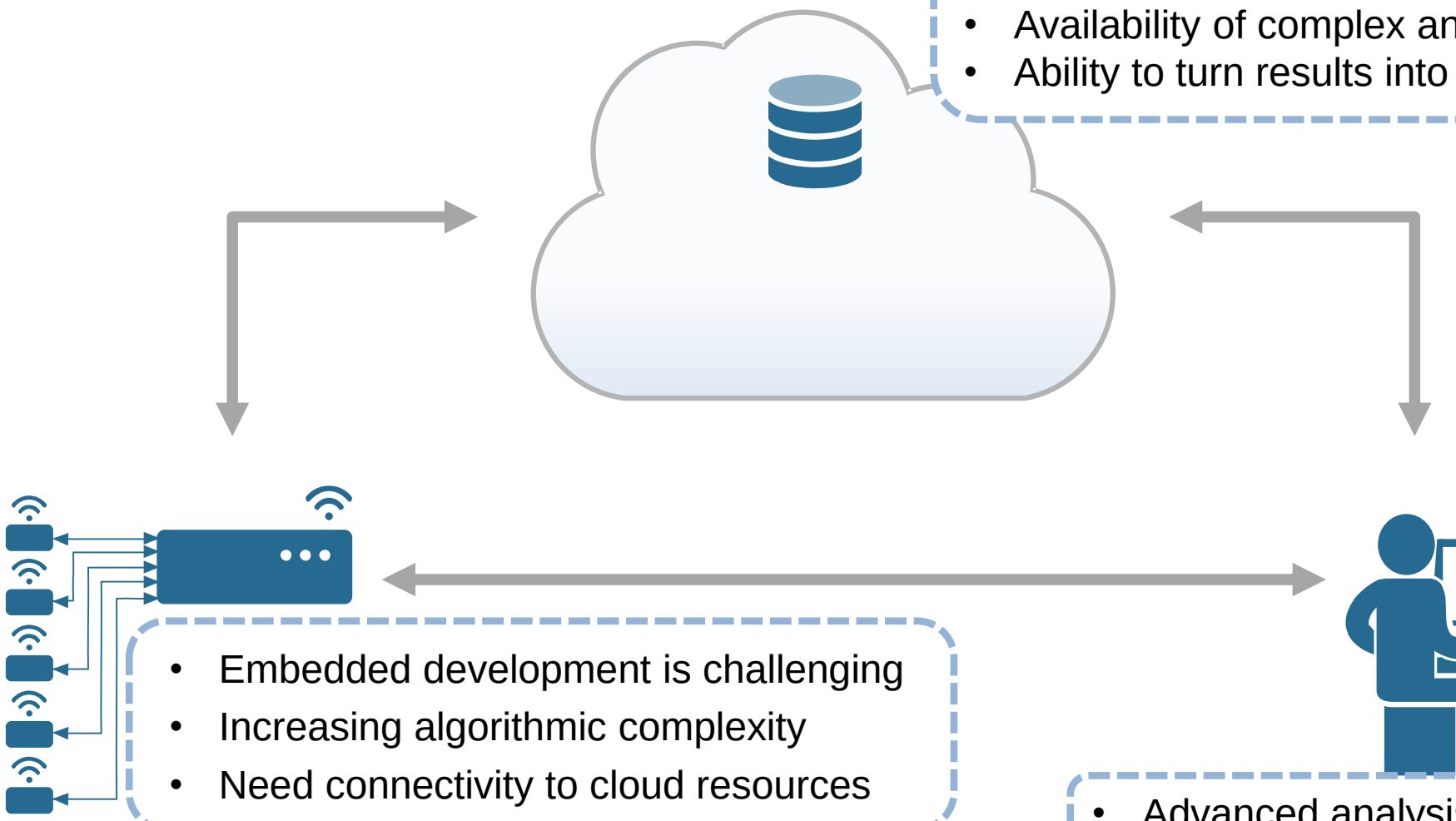
- **Analytics is key to getting value of IoT system**
- **Prototyping is hard**

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

- Streaming data management and storage
- Availability of complex analysis as services
- Ability to turn results into actions

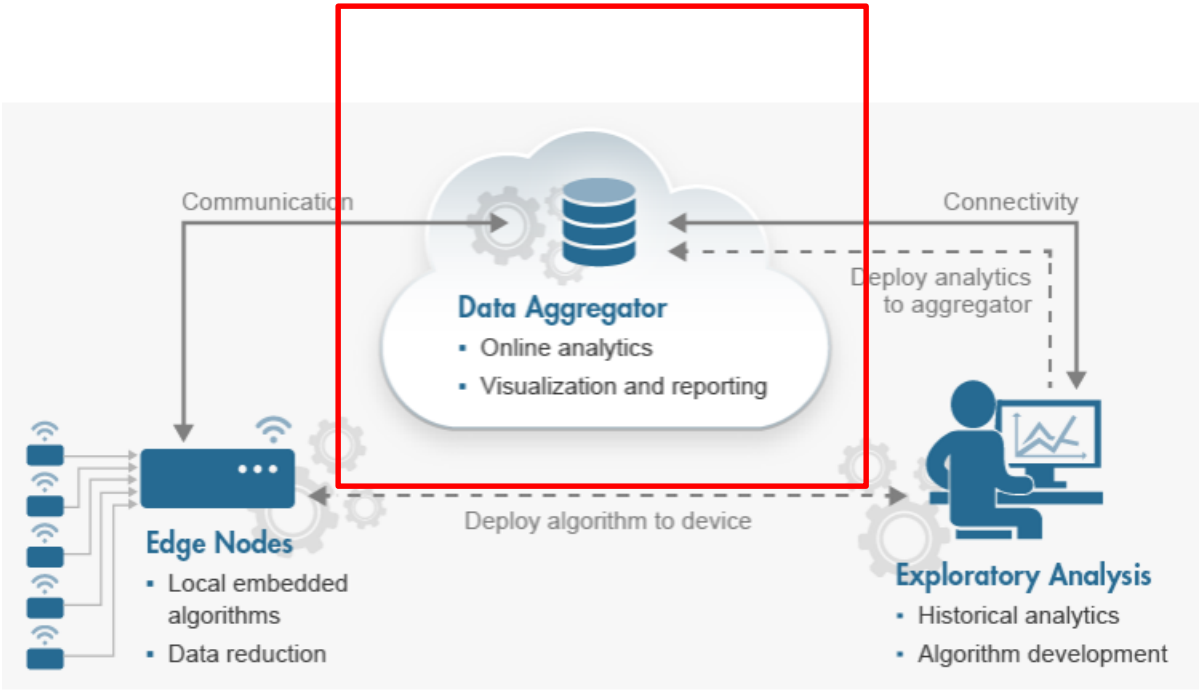


- Embedded development is challenging
- Increasing algorithmic complexity
- Need connectivity to cloud resources

- Advanced analysis algorithms
- Tools for deployment and connectivity

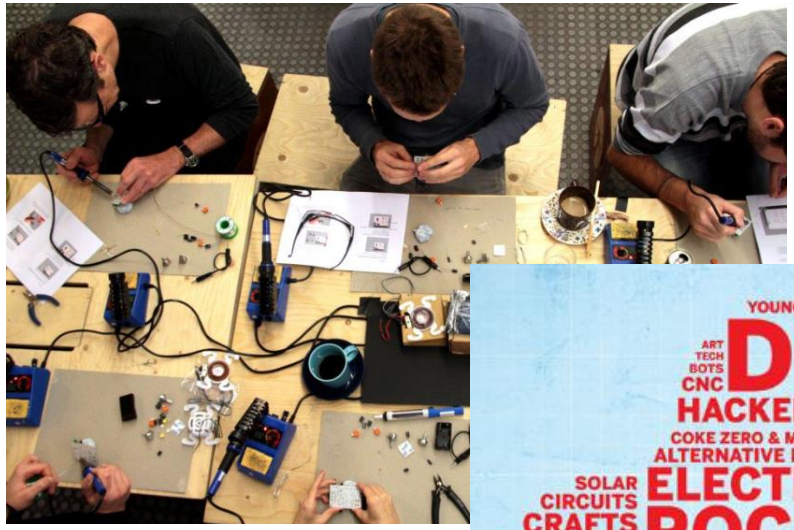
What is ThingSpeak?

- 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?

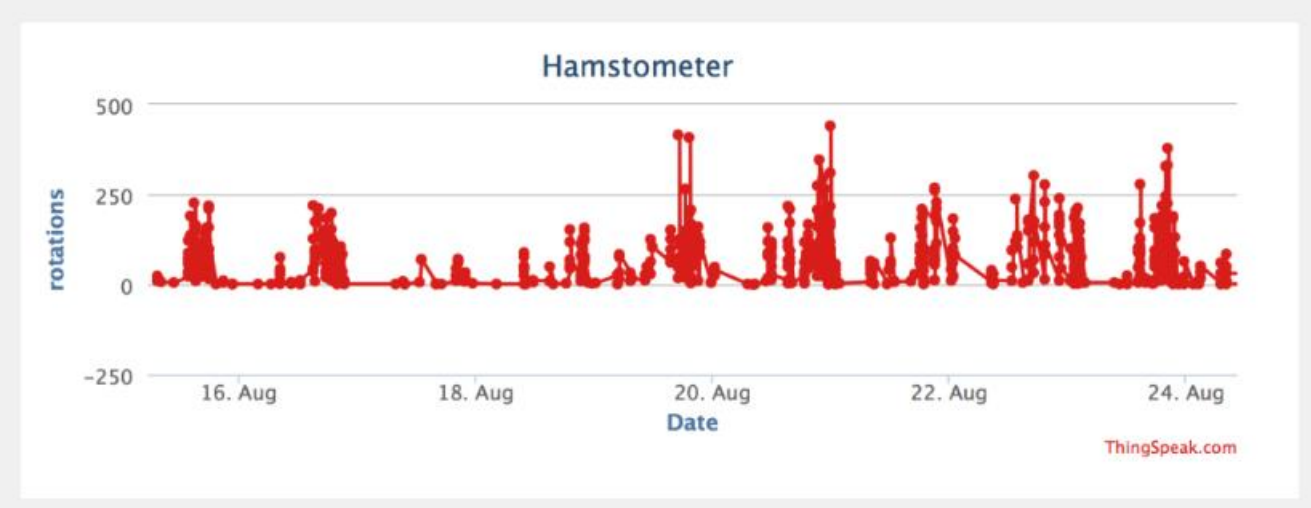
- Makers
- EDU
- Engineers prototyping



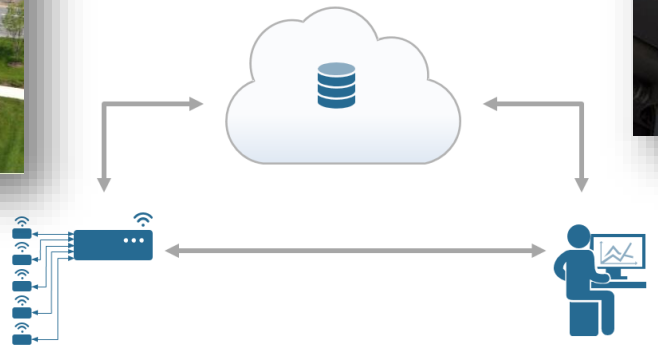
https://thingspeak.com/

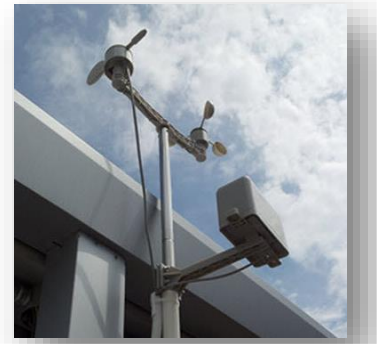
Common ThingSpeak applications

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



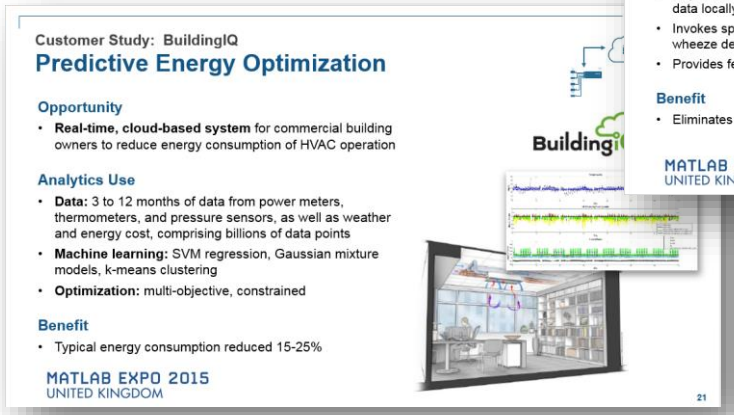
Some IoT examples

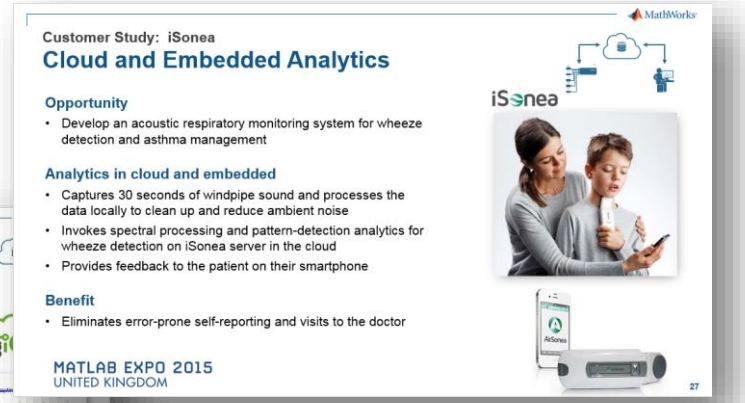




- Two all-in-MATLAB IoT examples

- Scaling up MATLAB to IoT – the whole picture





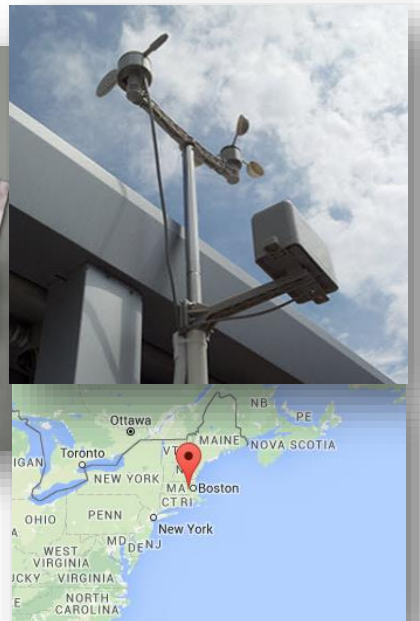
Example 1: Monitoring Weather

Objectives

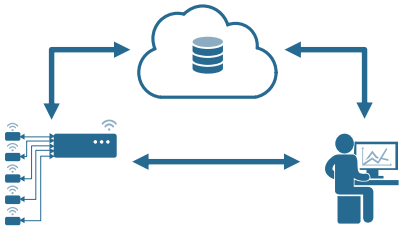
- Measure, explore, discover weather patterns
- Provide niche weather service

Solution

- Arduino station with weather sensors
- Cloud-based aggregation and analysis
- Full example available at makerzone.mathworks.com



Example 2: Monitoring Traffic

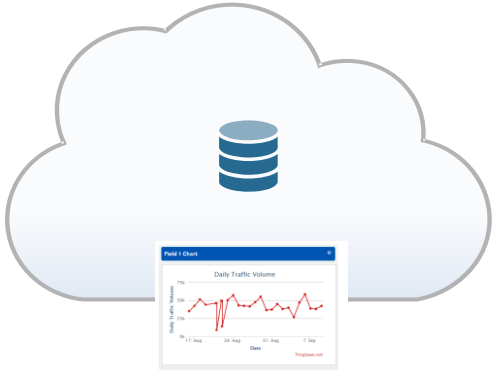


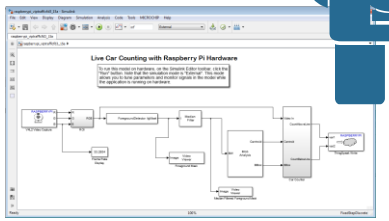
Objectives

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

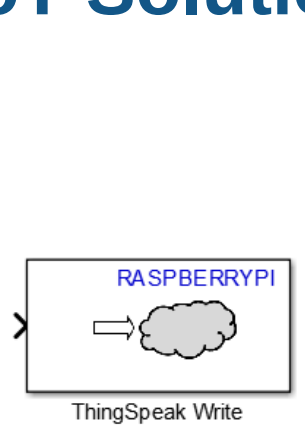
Solution

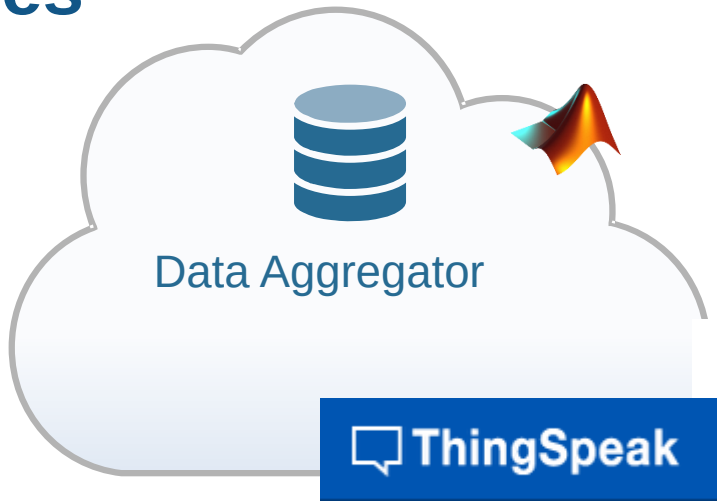
- RaspberryPi + webcam
- **Automated deployment of vision algorithms on embedded sensor**
- Full example available at makerzone.mathworks.com





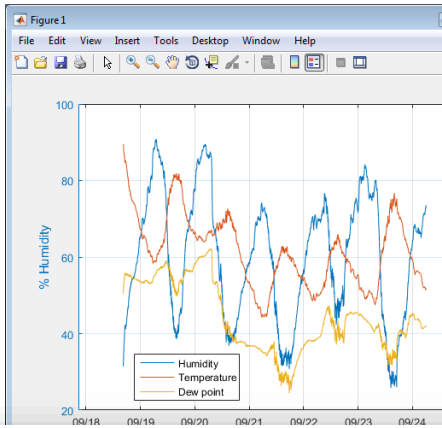
IoT Solutions Examples





Analyze

Analyze and visualize your data.

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thingSpeakRead(12397,'
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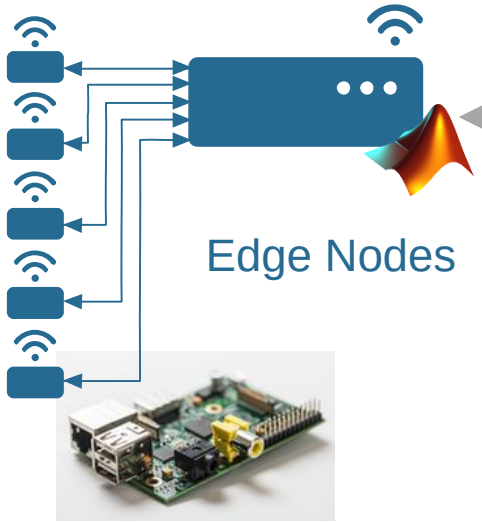
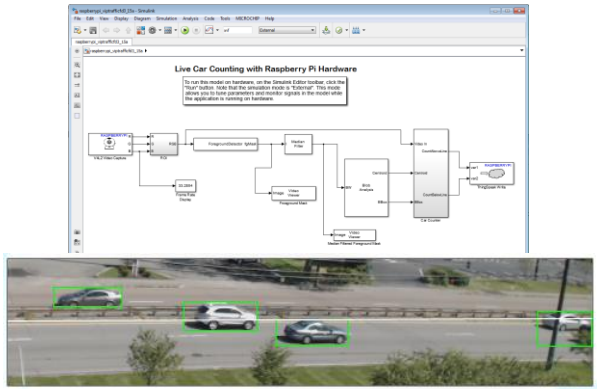


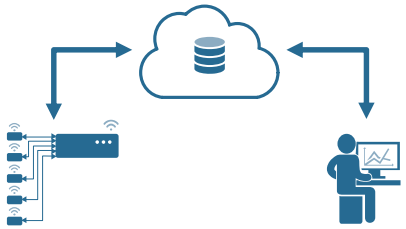


Exploratory Analysis

- Historical analytics
- Algorithm development

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

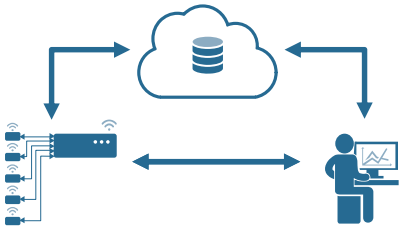
- **Data:** 3 to 12 months of data from power meters, thermometers, and pressure sensors, as well as weather and energy cost, comprising billions of data points
- **Machine learning:** SVM regression, Gaussian mixture models, k-means clustering
- **Optimization:** multi-objective, constrained

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

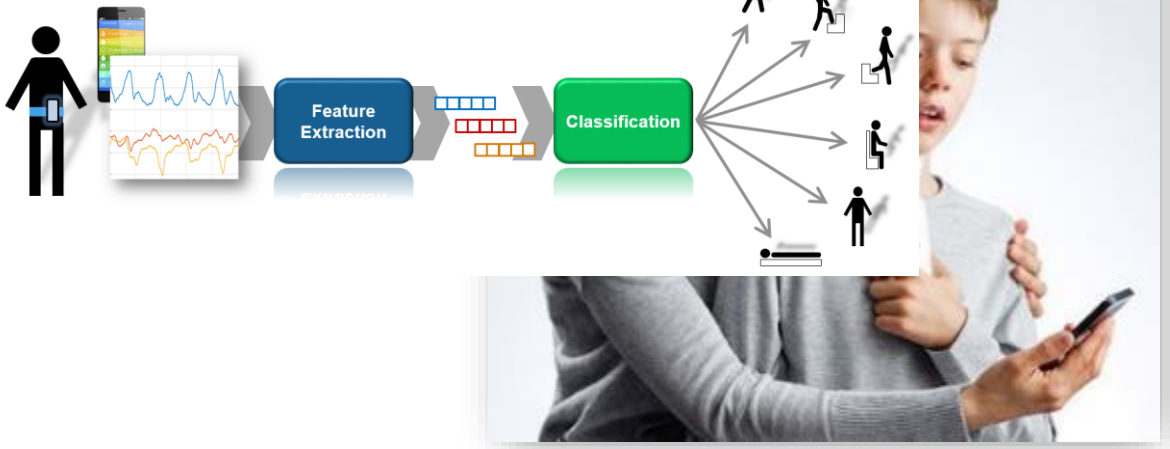
Analytics in cloud and embedded

- 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

- 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

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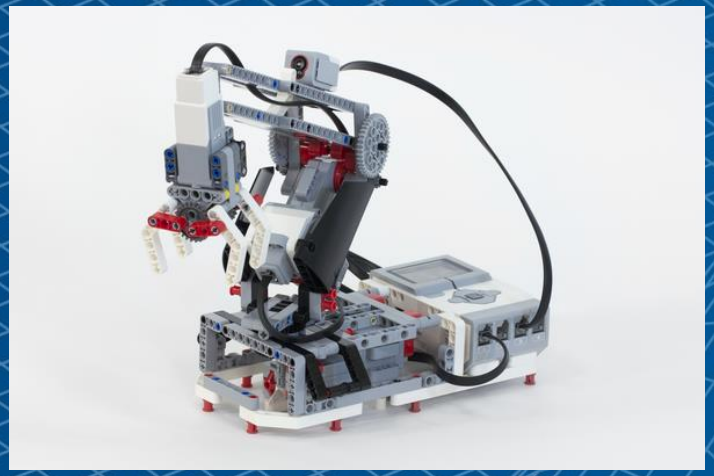
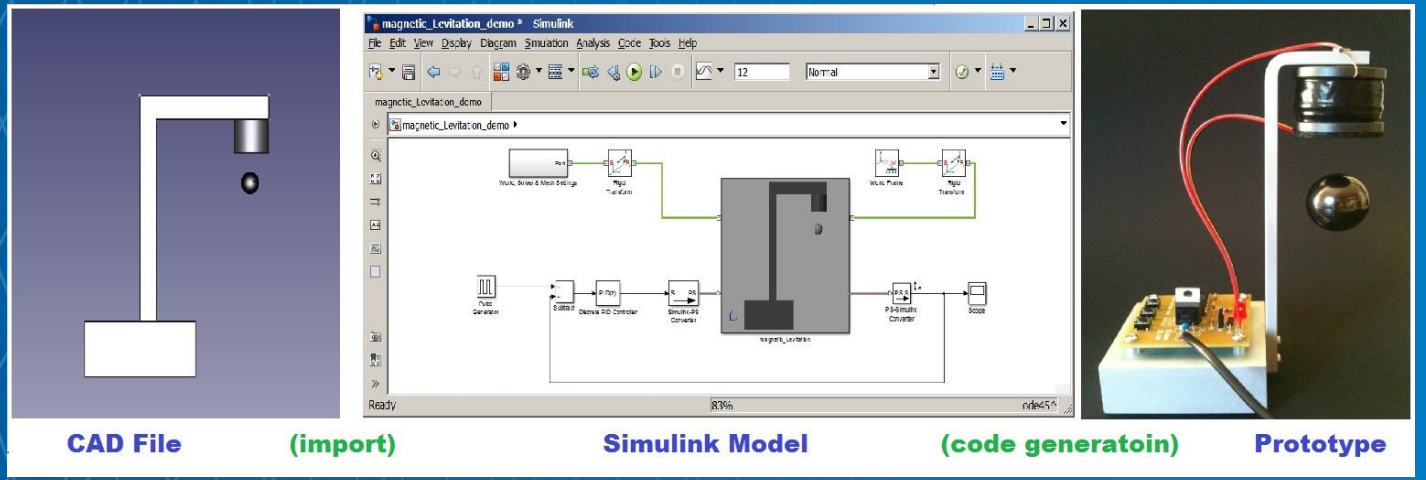
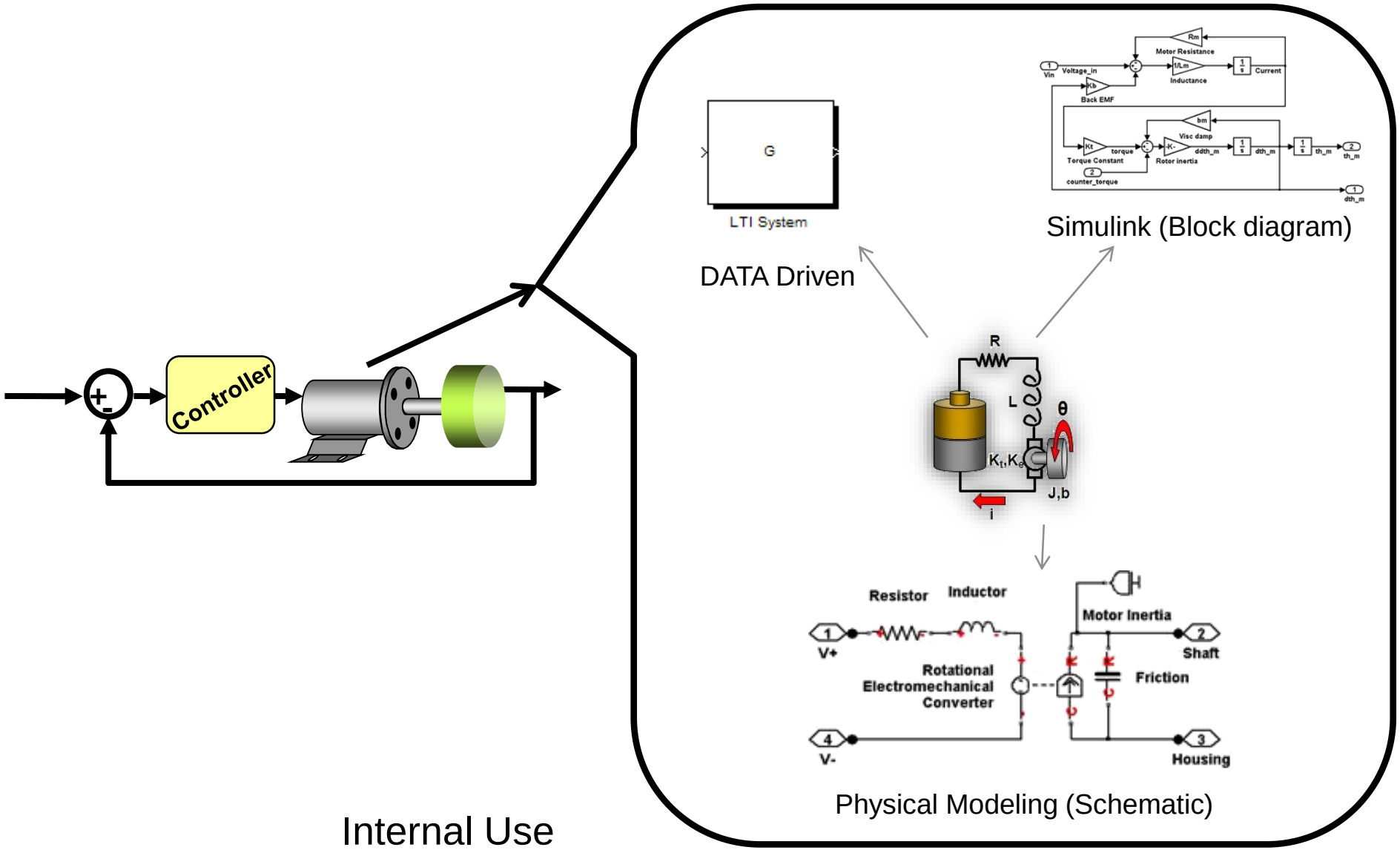




Example

DEMO: pick and place robot

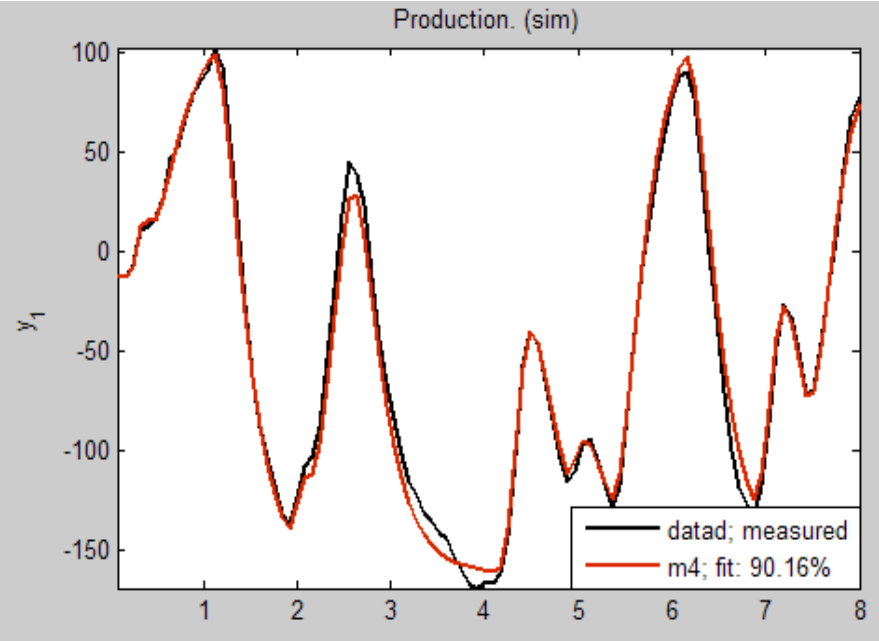
Different modeling approaches



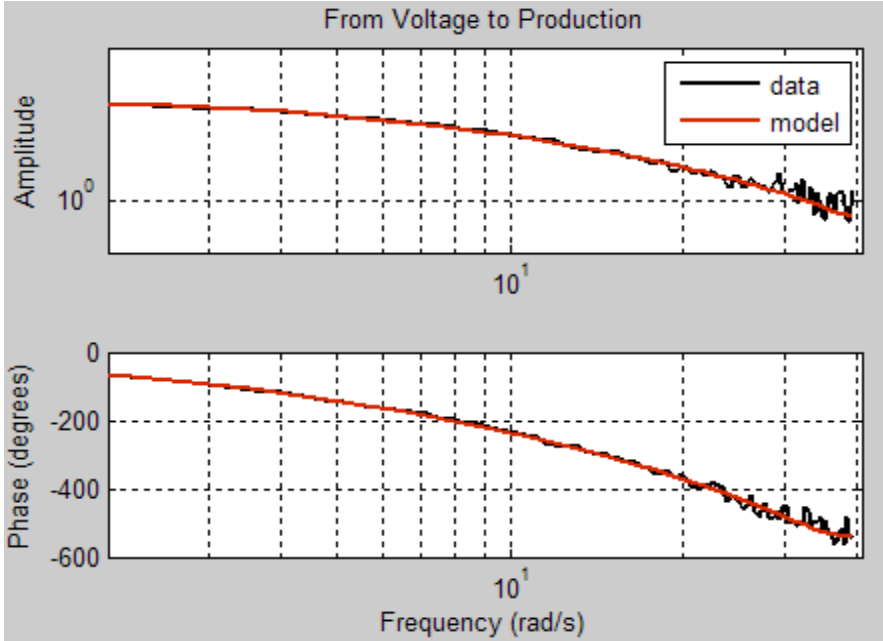
Demo: Creating Linear Models from Data

- Modeling process dynamics
- Using models in Simulink

Fit time domain data

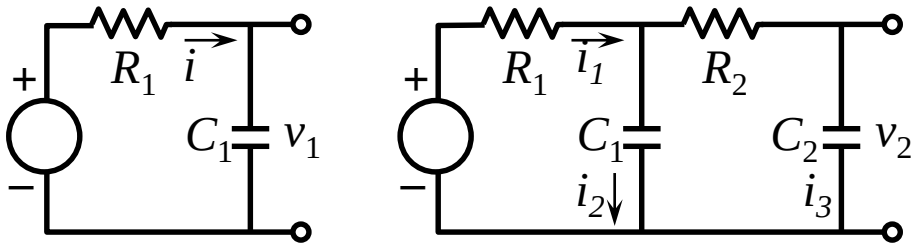


Fit frequency domain data

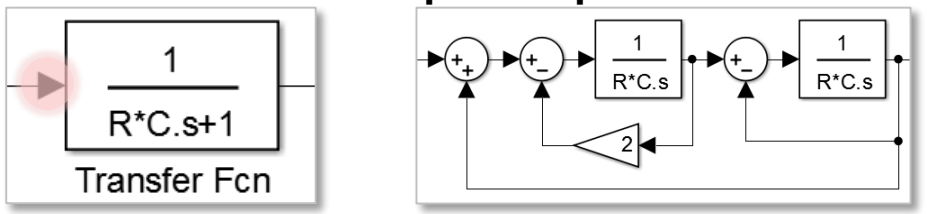


Physical Modeling Within Simulink

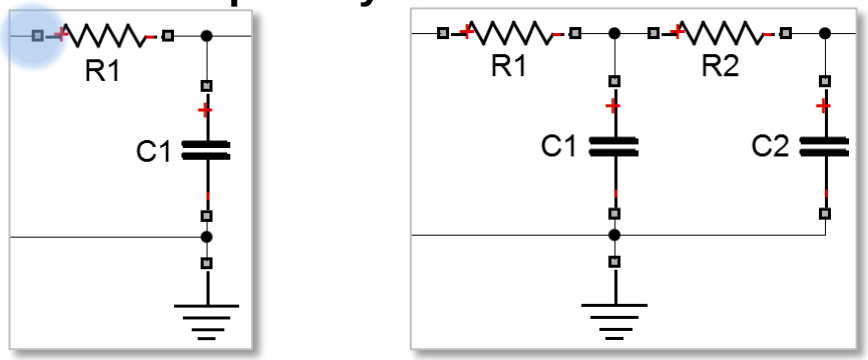
- Simulink is best known for signal-based modeling
  - Causal, or input/output
- Simscape enables bidirectional flow of power between components
- System level equations:
  - Formulated automatically
  - Solved simultaneously
  - Cover multiple domains

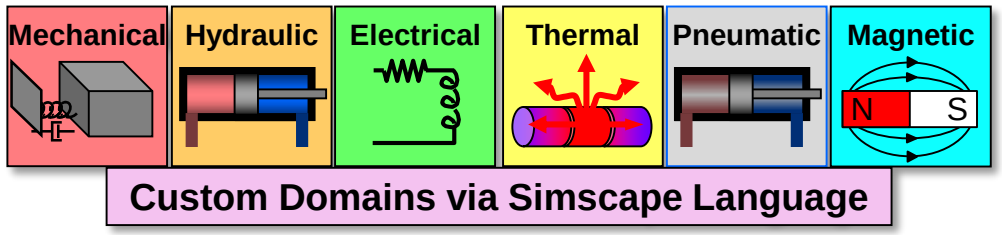


Simulink: Input/Output

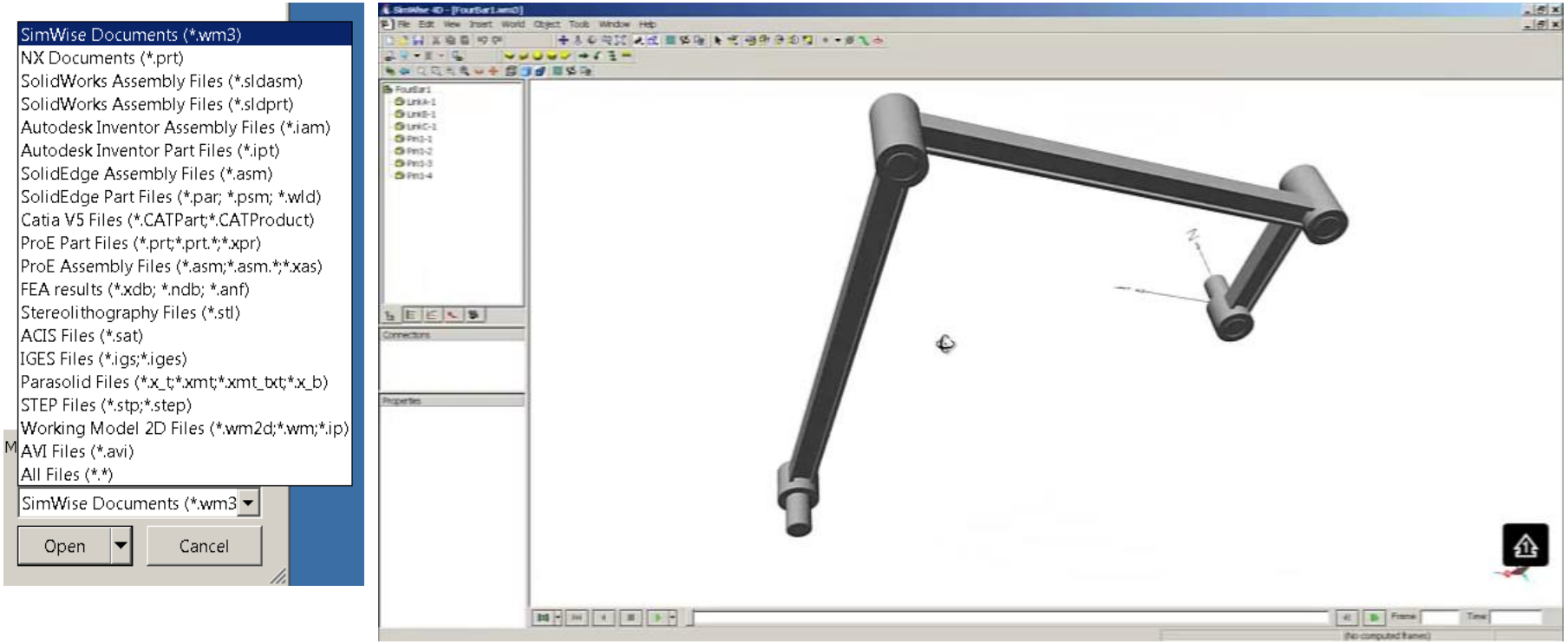


Simscape: Physical Networks





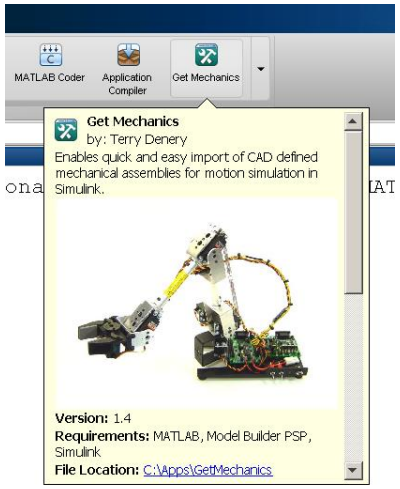
Importing CAD models

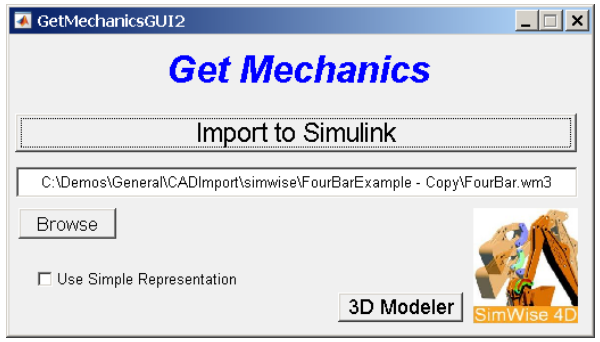


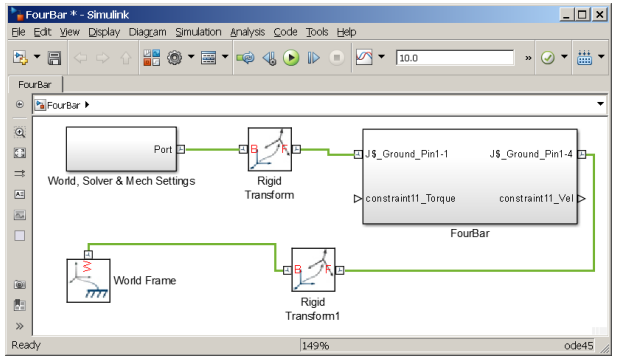
Open the CAD model in Simwise 4D

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

Automatically Create SimMechanics Models using GetMechanics App

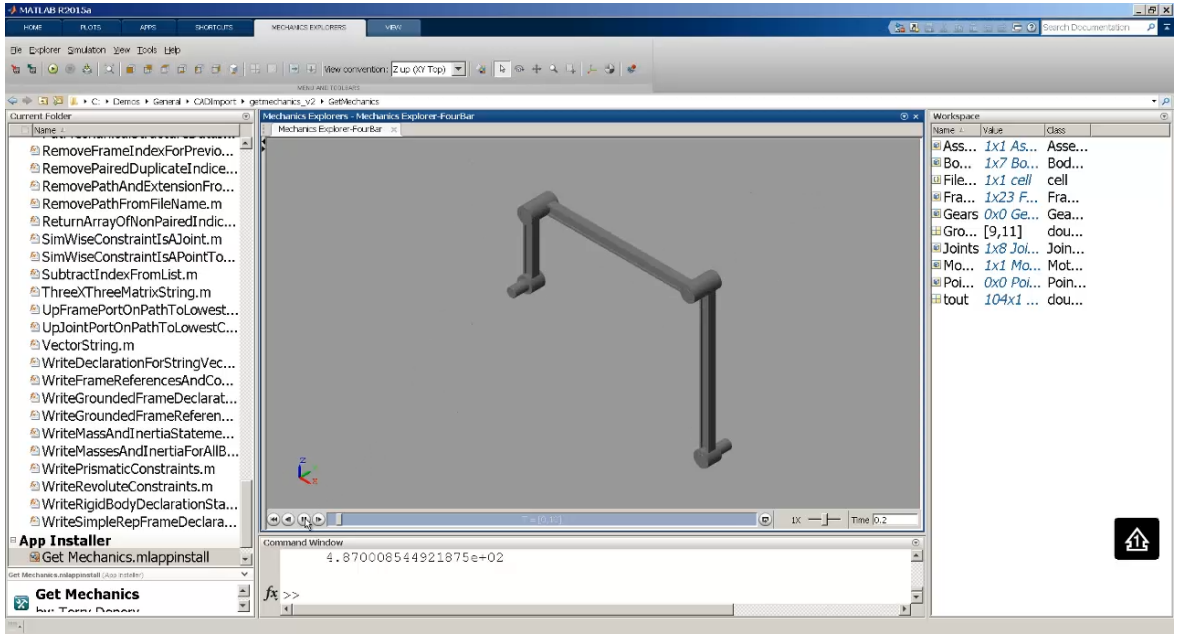




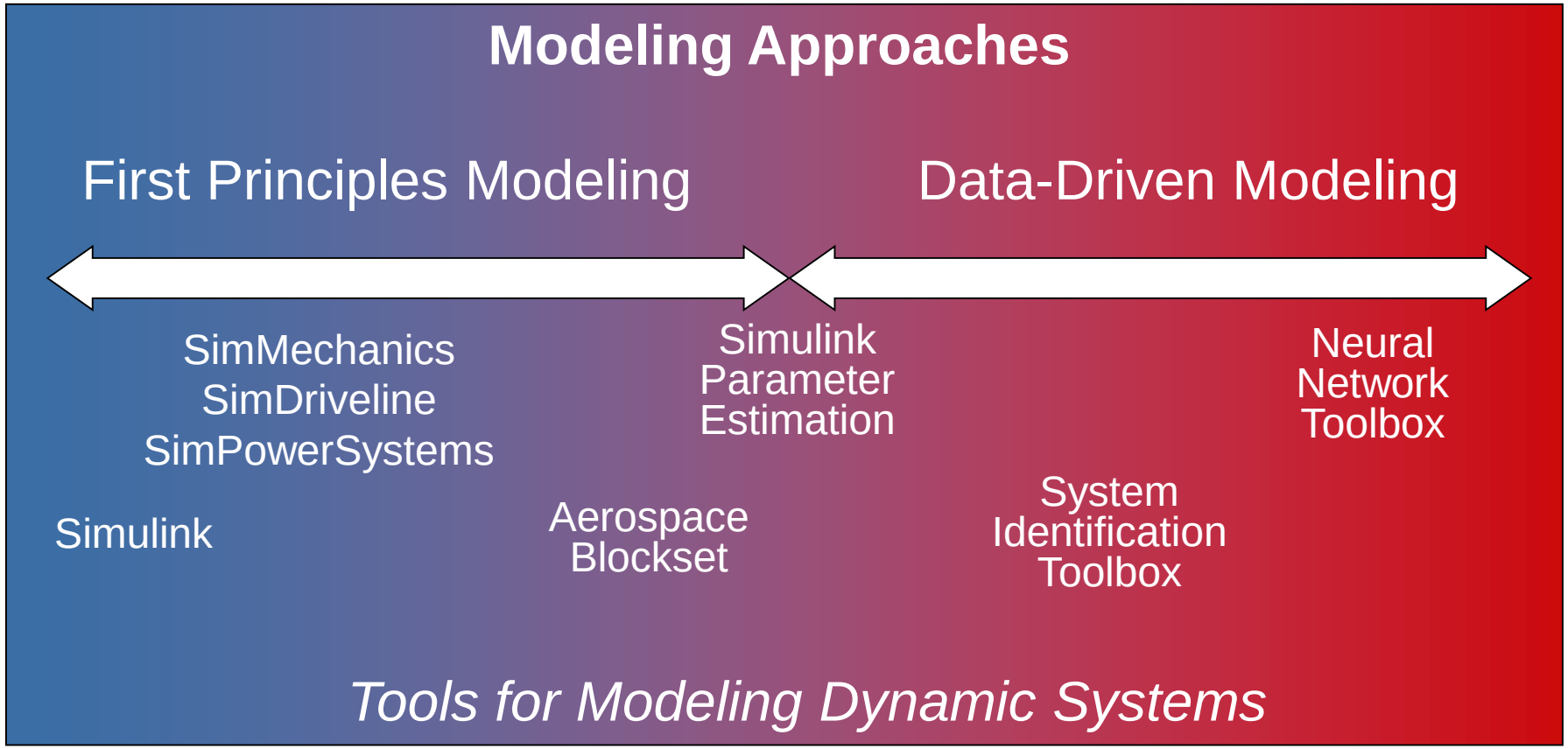


GetMechanics App can import SimWise *.wm3 file

To get GetMechanics App Contact MathWorks

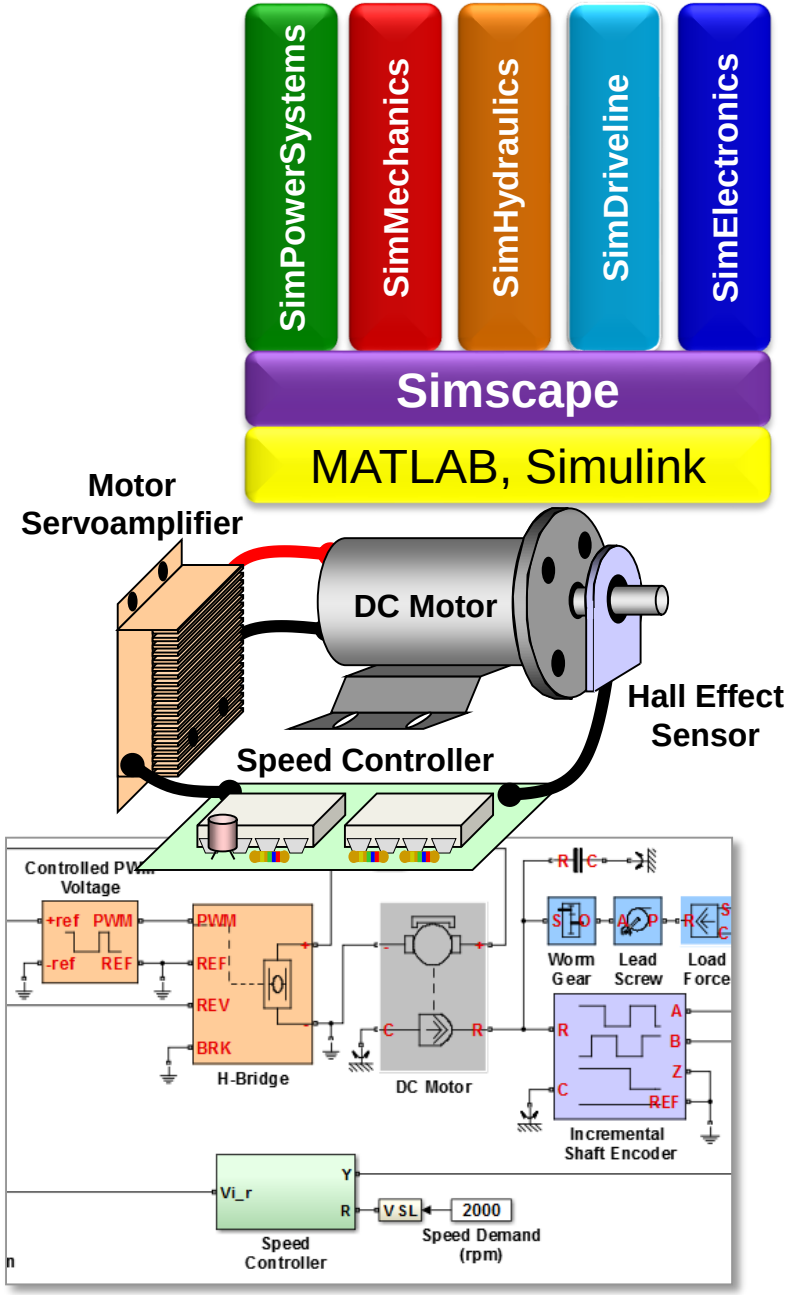


Modeling Dynamic Systems in Simulink



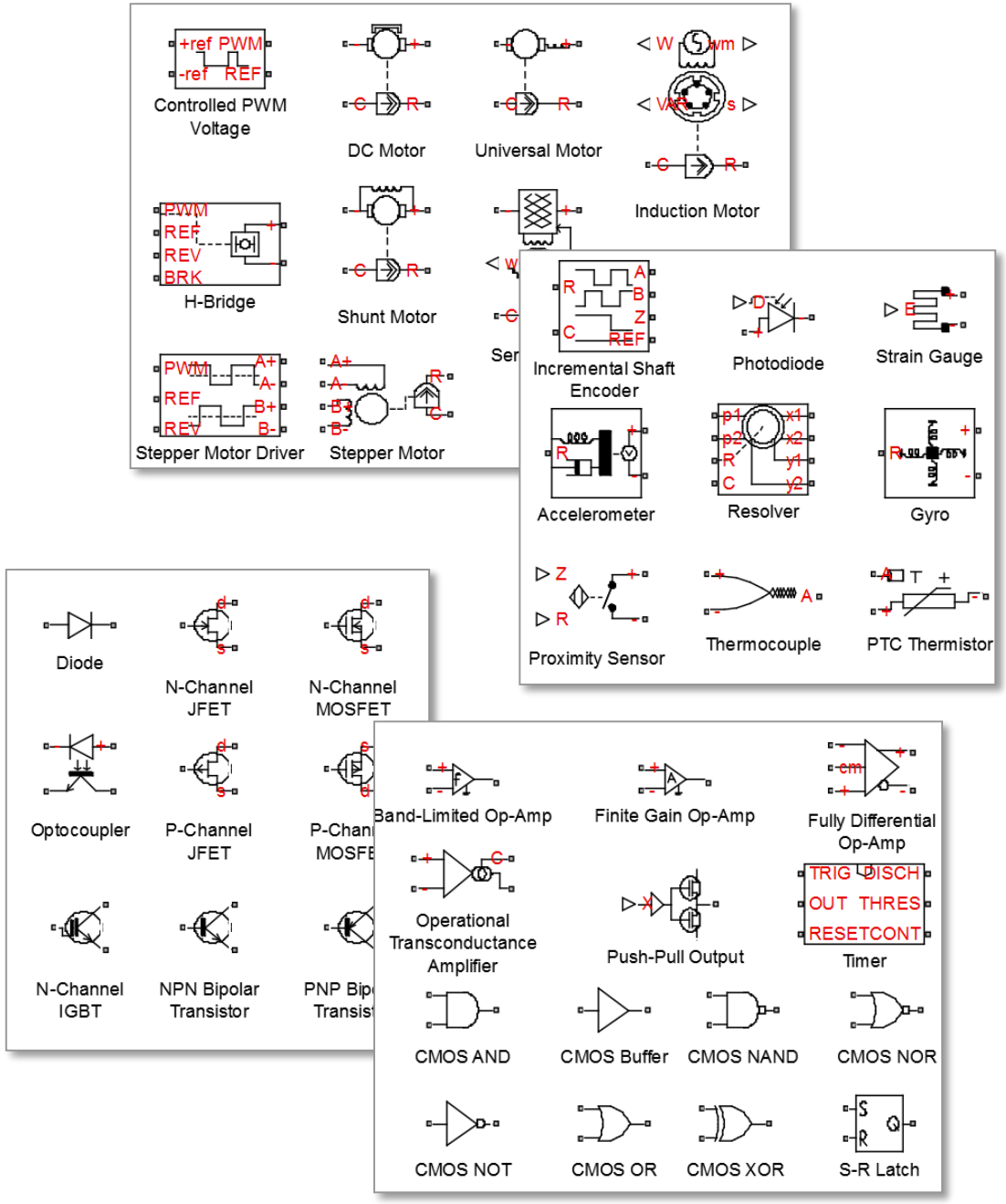
Introduction to SimElectronics

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



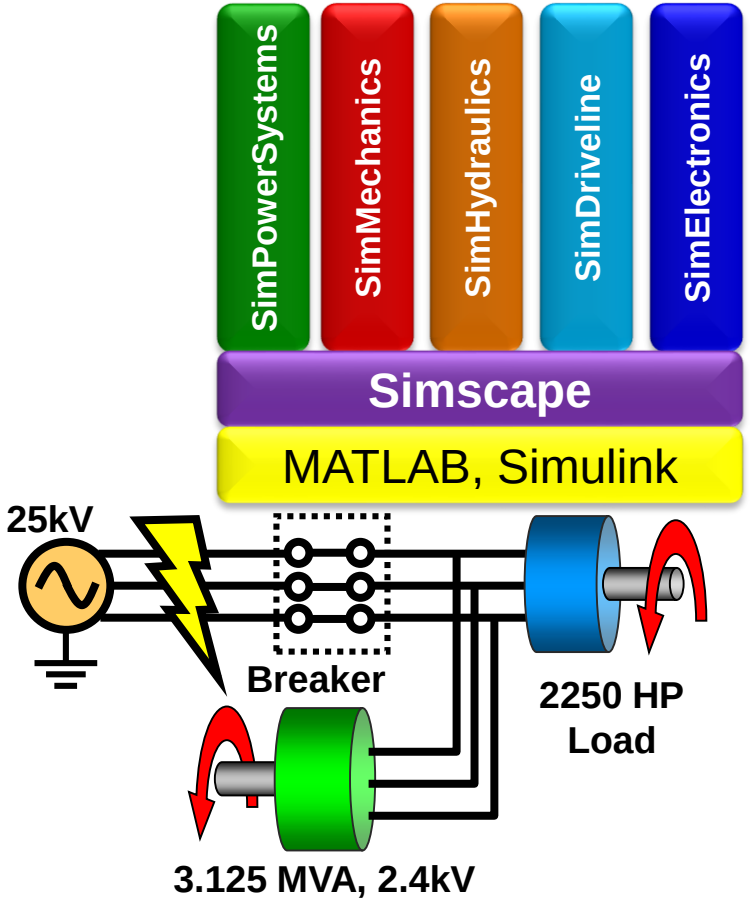
Extensive Component Libraries

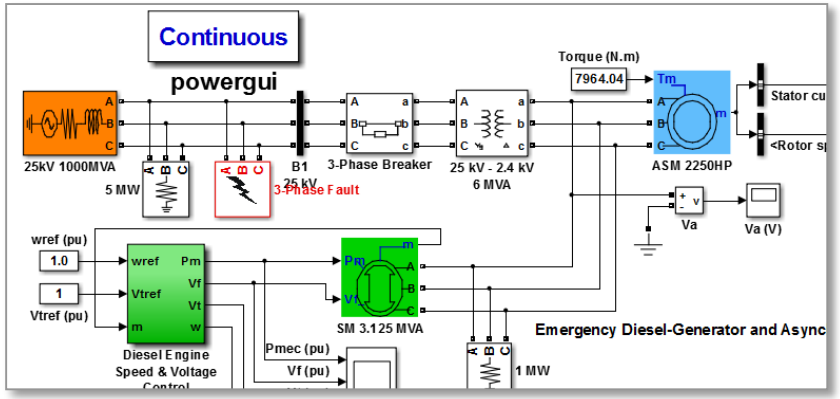
- More than 90 component models
  - Actuators, drivers
  - Sensors
  - Semiconductors
  - Integrated circuits
- Models look like schematics
  - Easy to read and interpret



Introduction to SimPowerSystems

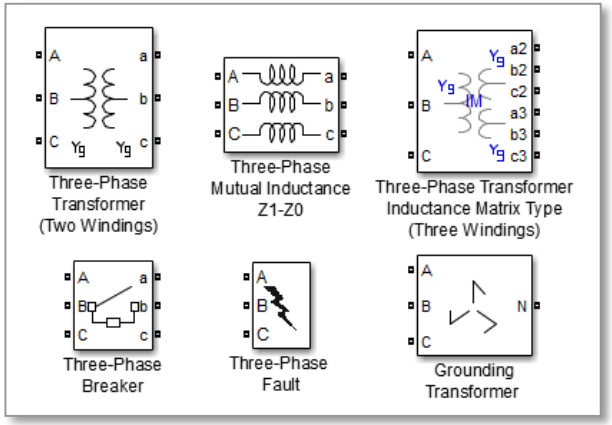
- Enables physical modeling (acausal) of electrical power systems and electric drives
- Electrical system topology represented by schematic circuit
- Used by electrical, system and control engineers to develop plant models and test control systems

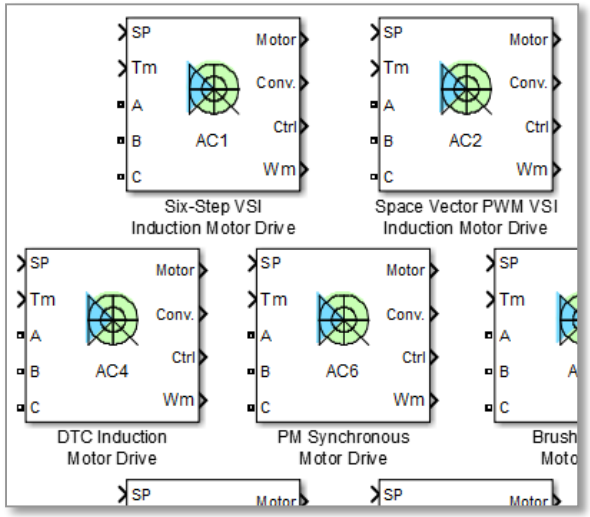


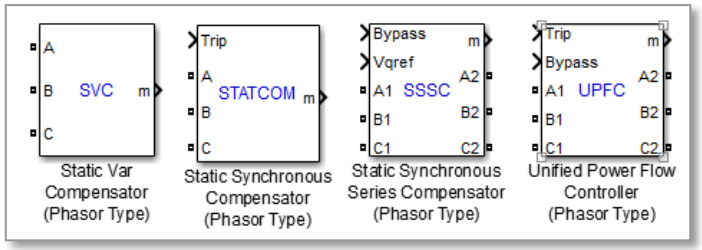


Quickly Build Electrical Systems

- 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

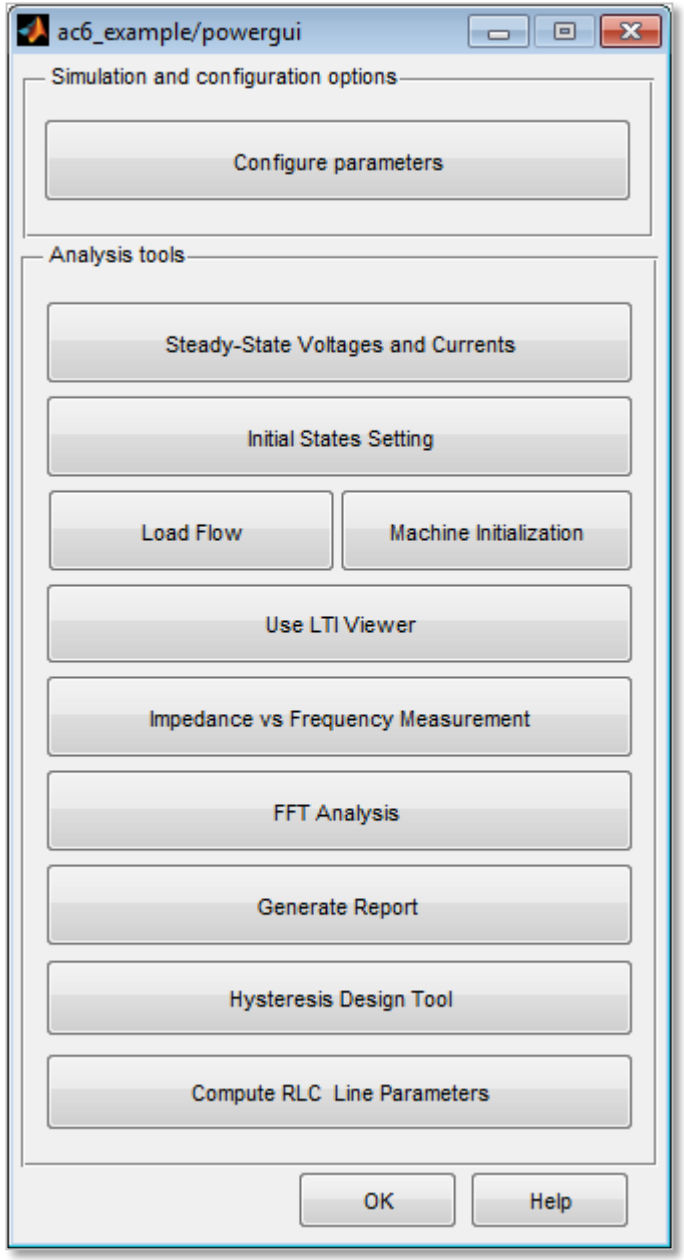




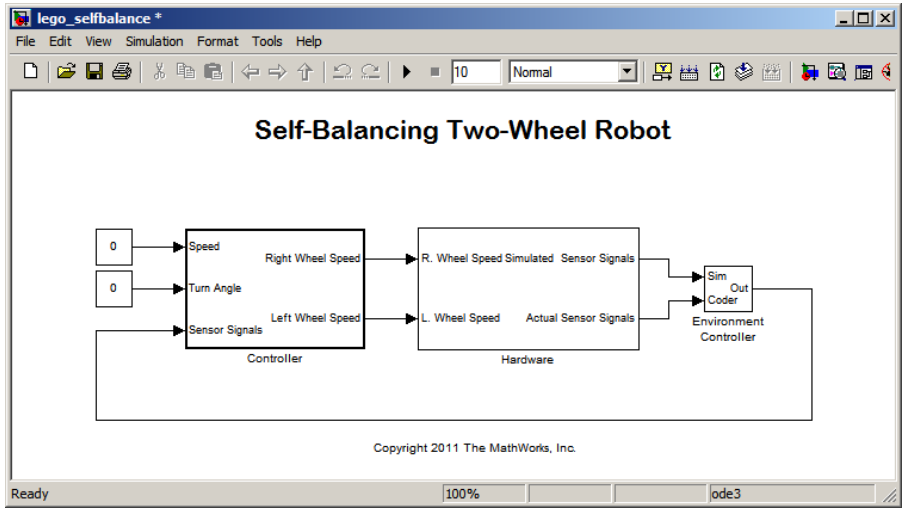


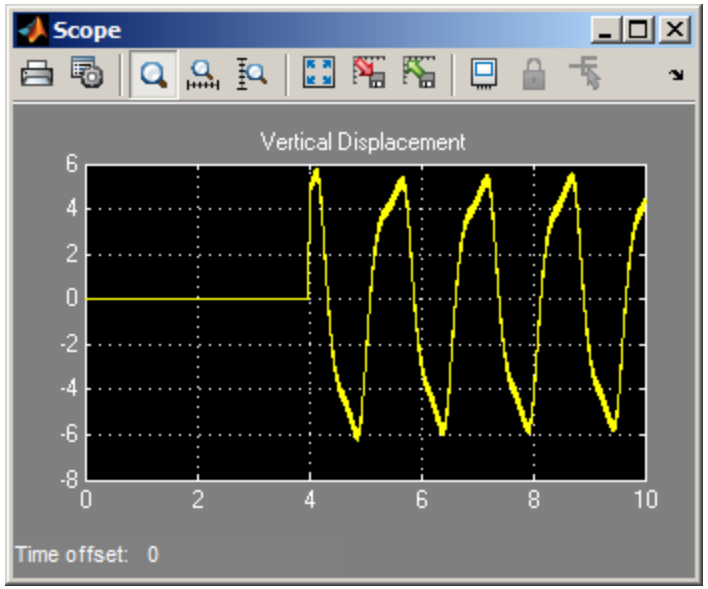
Electrical System Analysis

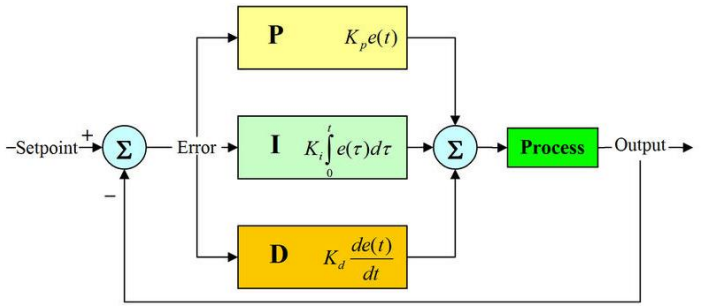
- Quick access to tools for common analysis tasks:
  - Display steady-state V and I
  - Display and modify initial states
  - Perform load flows
  - Display impedance measurements
  - FFT analysis
  - Report generation
- Multiple simulation modes
  - Discrete and phasor modes enable you to speed up simulations



Modeling the Controller







PID

Know your plant/system - Linearization

Design the controller with linear plant model

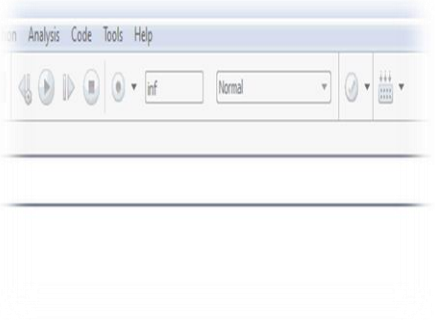
Test controller with non-linear plant in closed-loop

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®

new

Raspberry Pi ®

new

Machine Learning & Data Analytics

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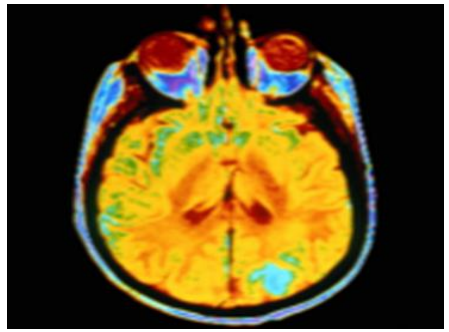
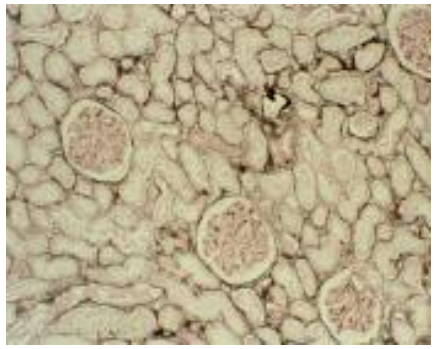
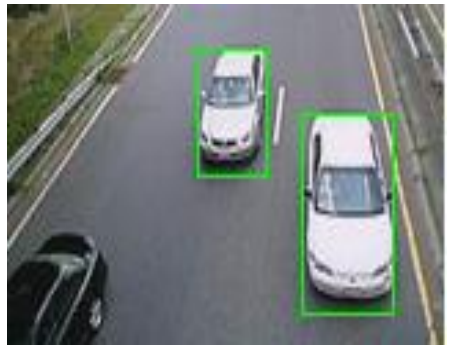
Machine Learning is Everywhere

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

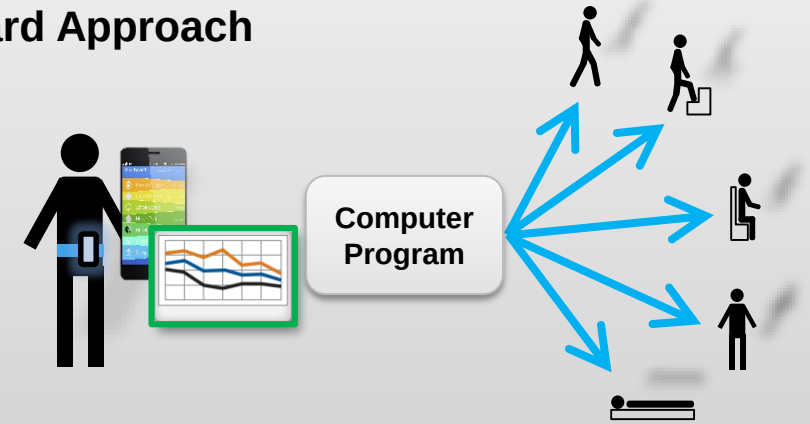


Machine Learning

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

Task: Human Activity Detection

Standard Approach



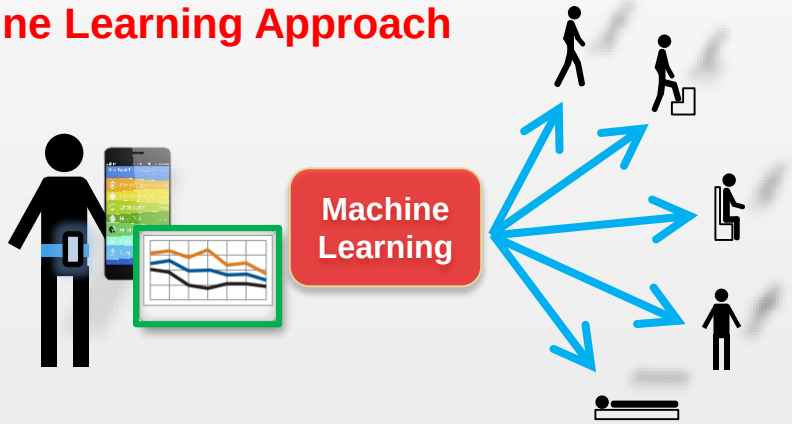
Hand Written Program

If X_acc > 0.5
then “SITTING”
If Y_acc < 4 and Z_acc > 5
then “STANDING”
…

Formula or Equation

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

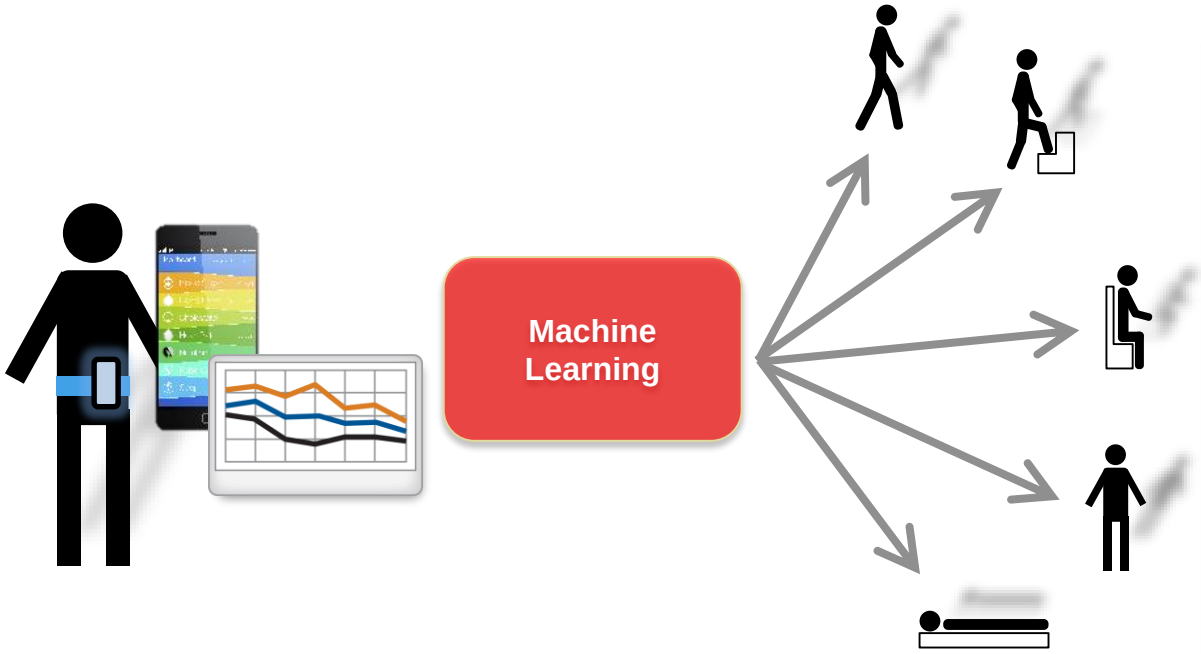
Machine Learning Approach

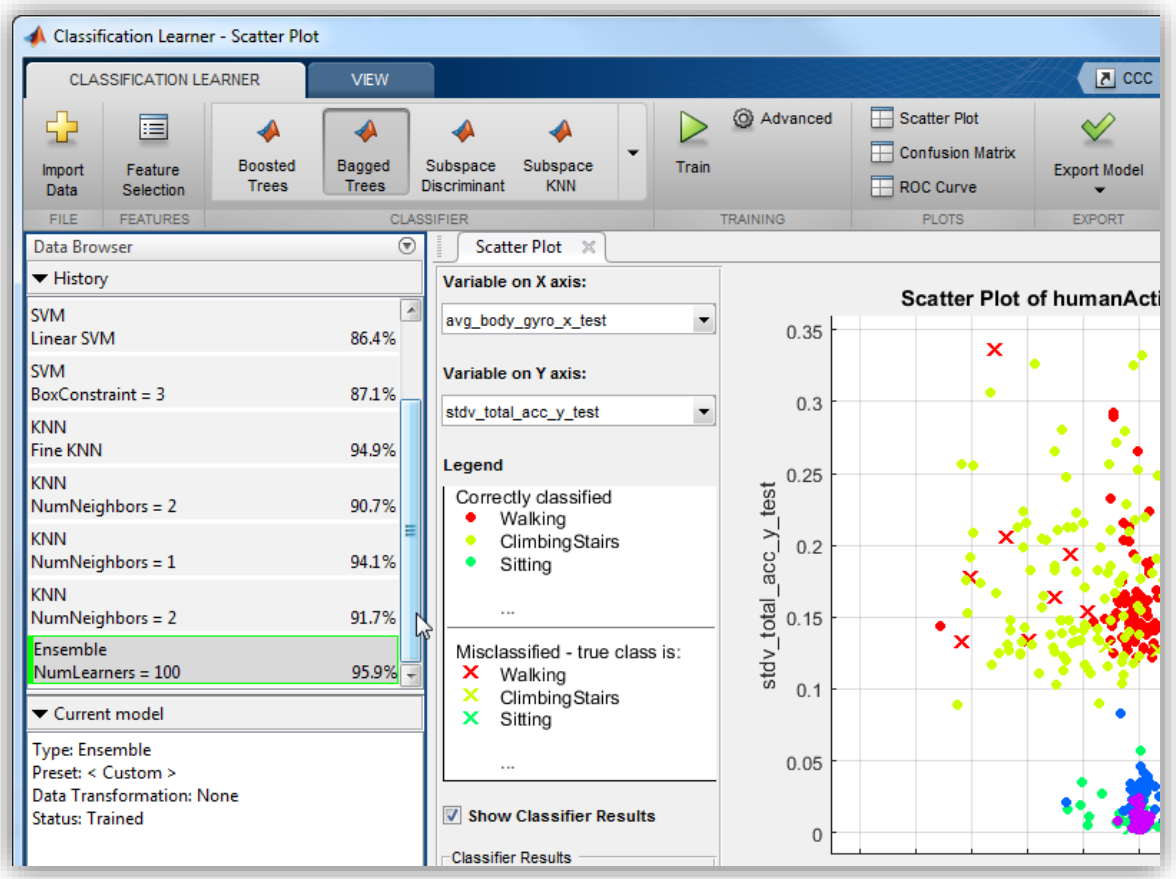


$model$: Inputs → Outputs

$$model = <^{\textbf{Machine Learning Algorithm}}>(sensor\_data, activity)$$

Example: Human Activity Learning Using Mobile Phone Data





Data:

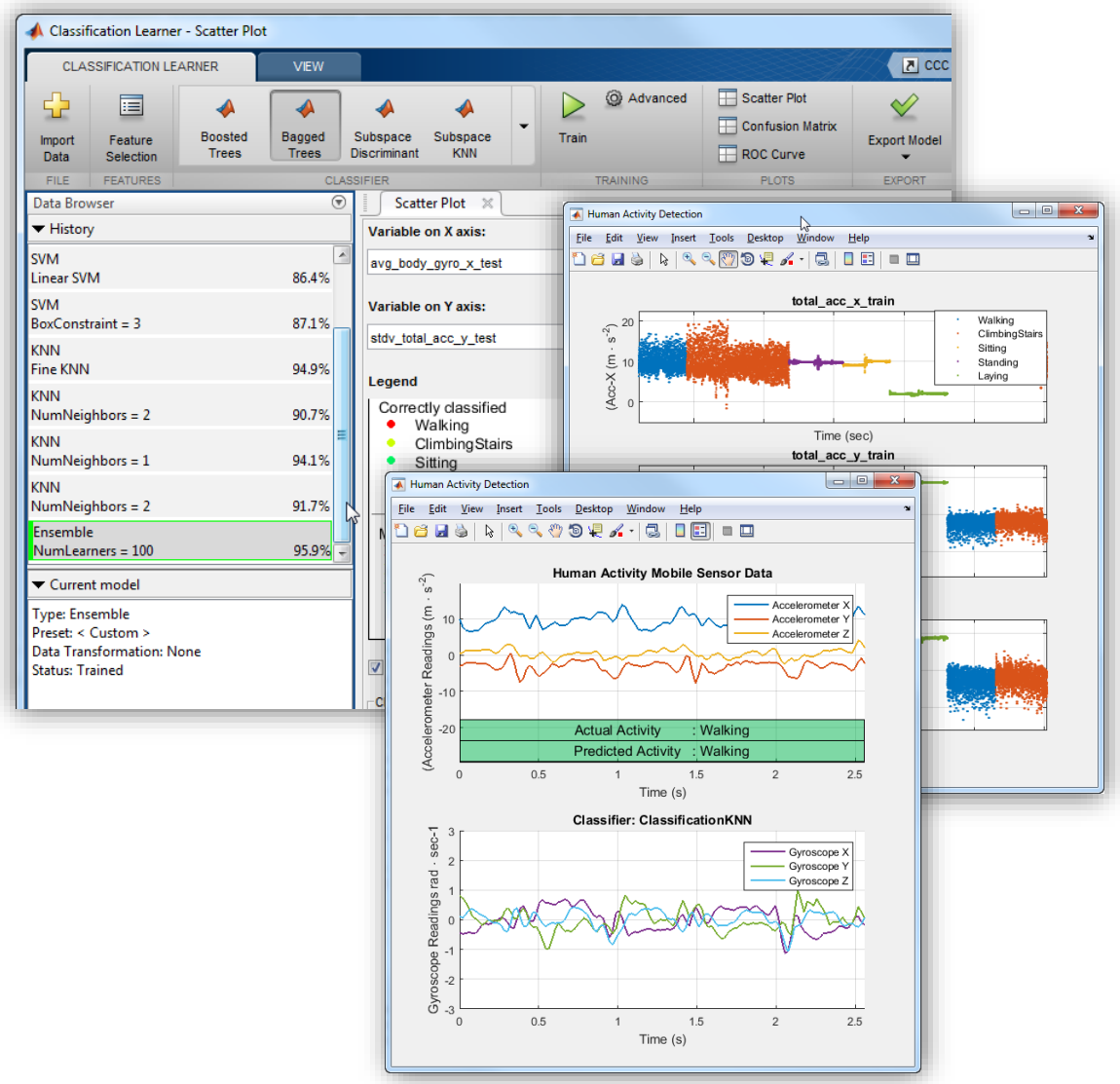
- 3-axial Accelerometer data
- 3-axial Gyroscope data

Example 1: Human Activity Learning Using Mobile Phone Data

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

Data:

Predictors	3-axial Accelerometer and Gyroscope data 
Response	Activity: 

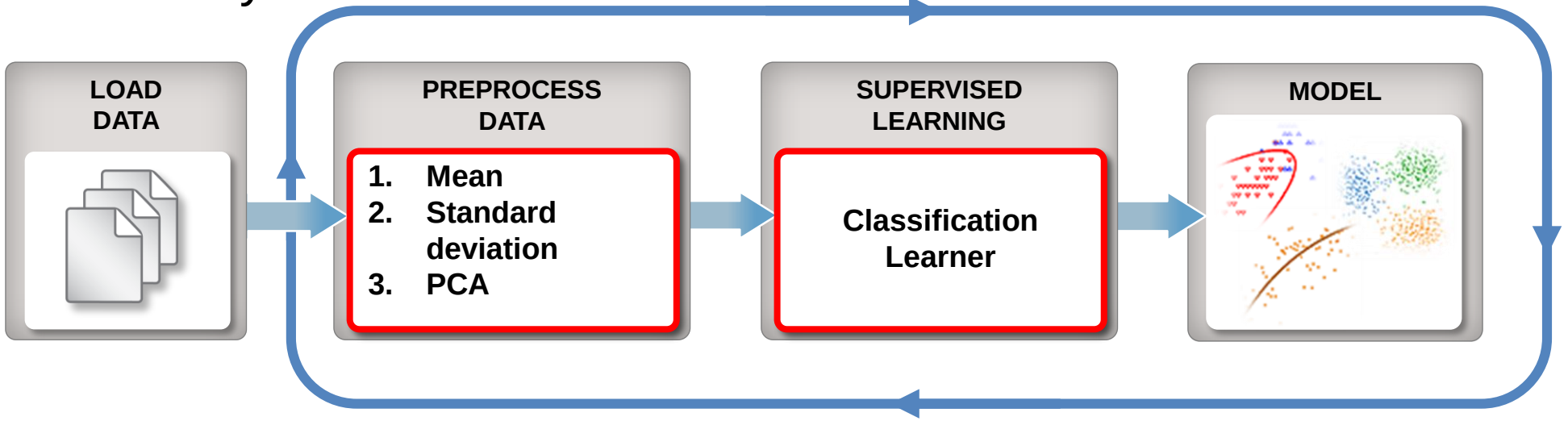


Approach:

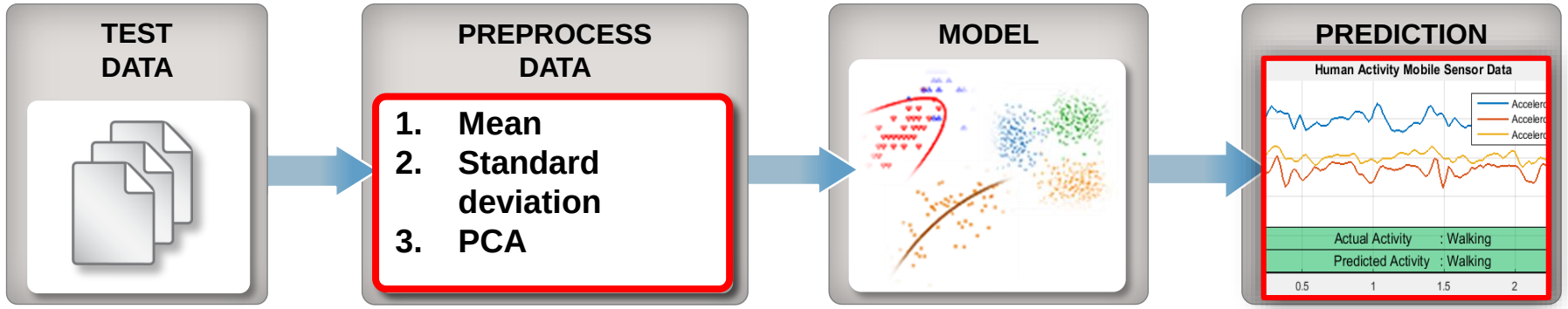
- Extract features from raw sensor signals
- Train and compare classifiers
- Test results on new sensor data

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

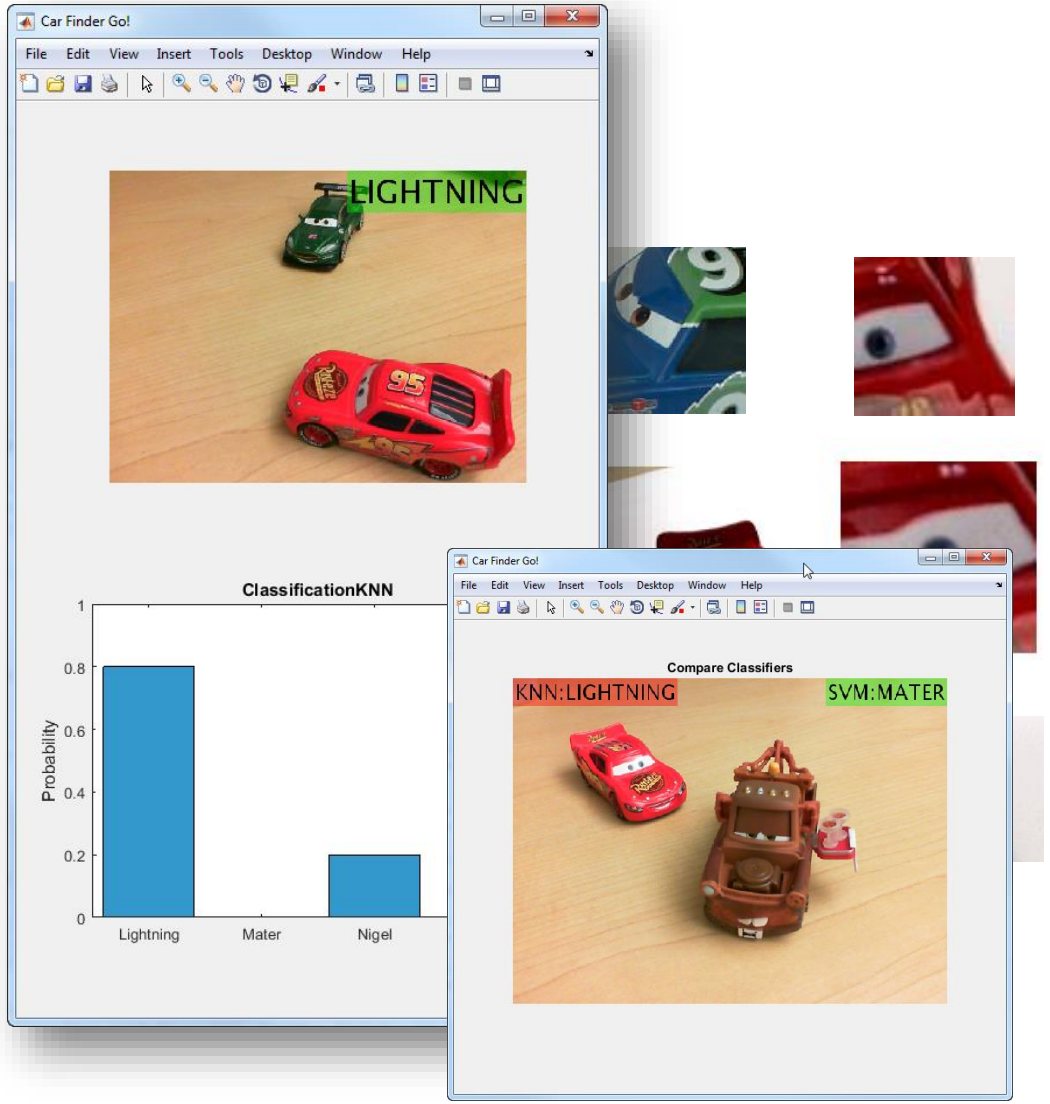
Objective: Train a classifier to identify car type from a webcam video

Data:

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

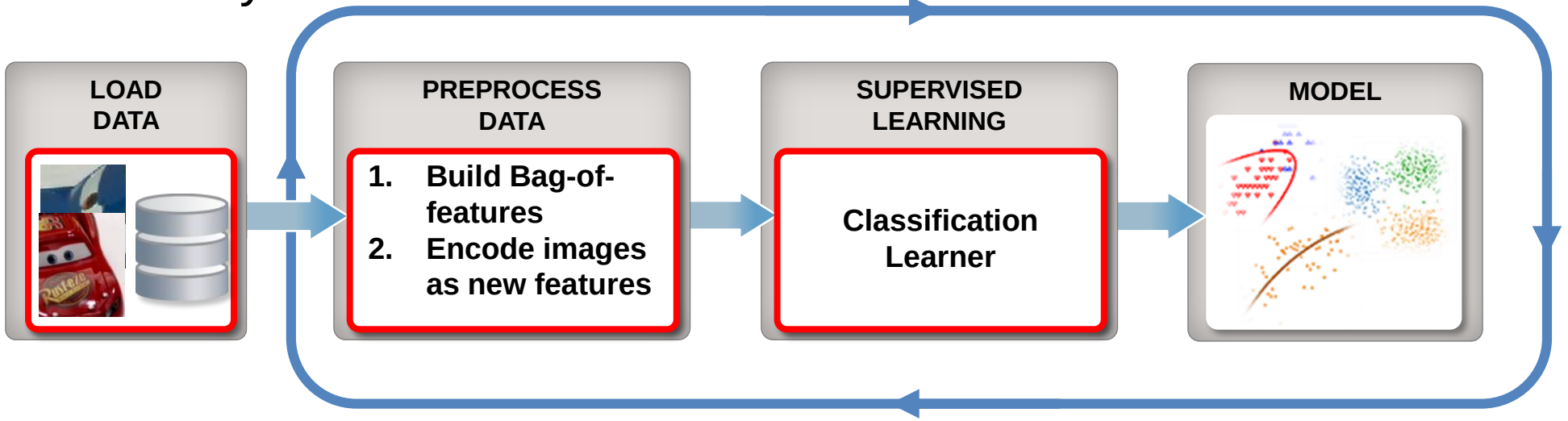
Approach:

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

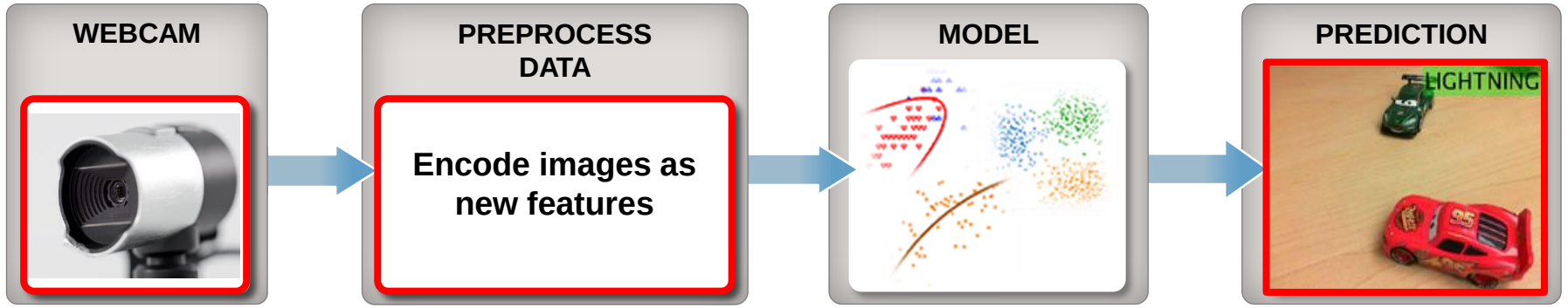


Machine Learning Workflow for Example 2

Train: Iterate till you find the best model

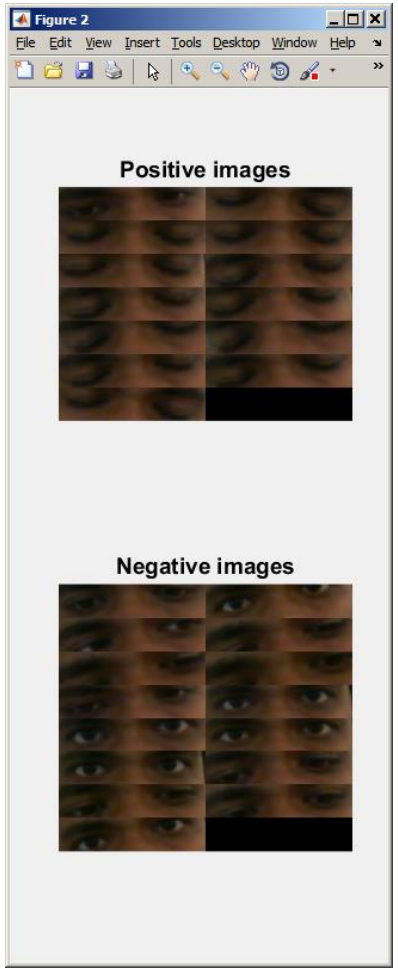


Predict: Integrate trained models into applications

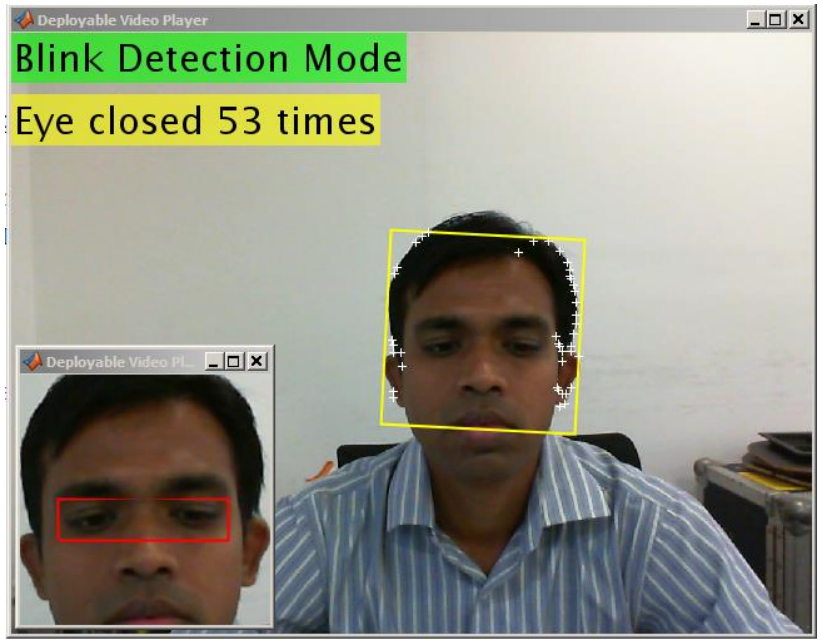


Detect Eye Blinks and Count Them

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



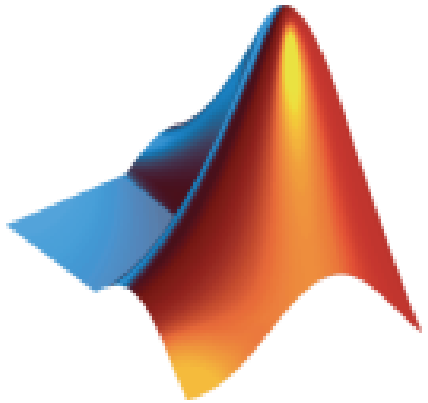
Training



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*

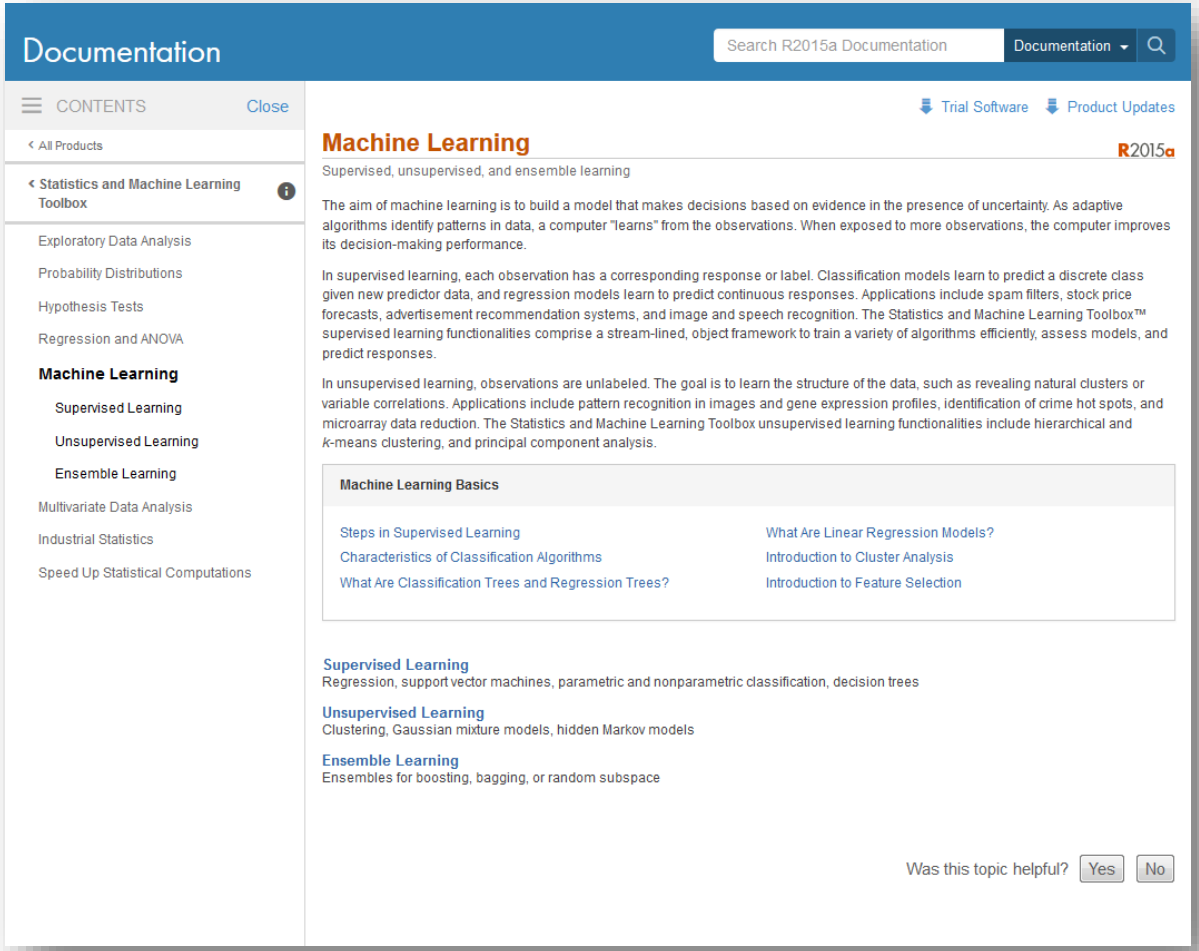
- MATLAB for Machine Learning

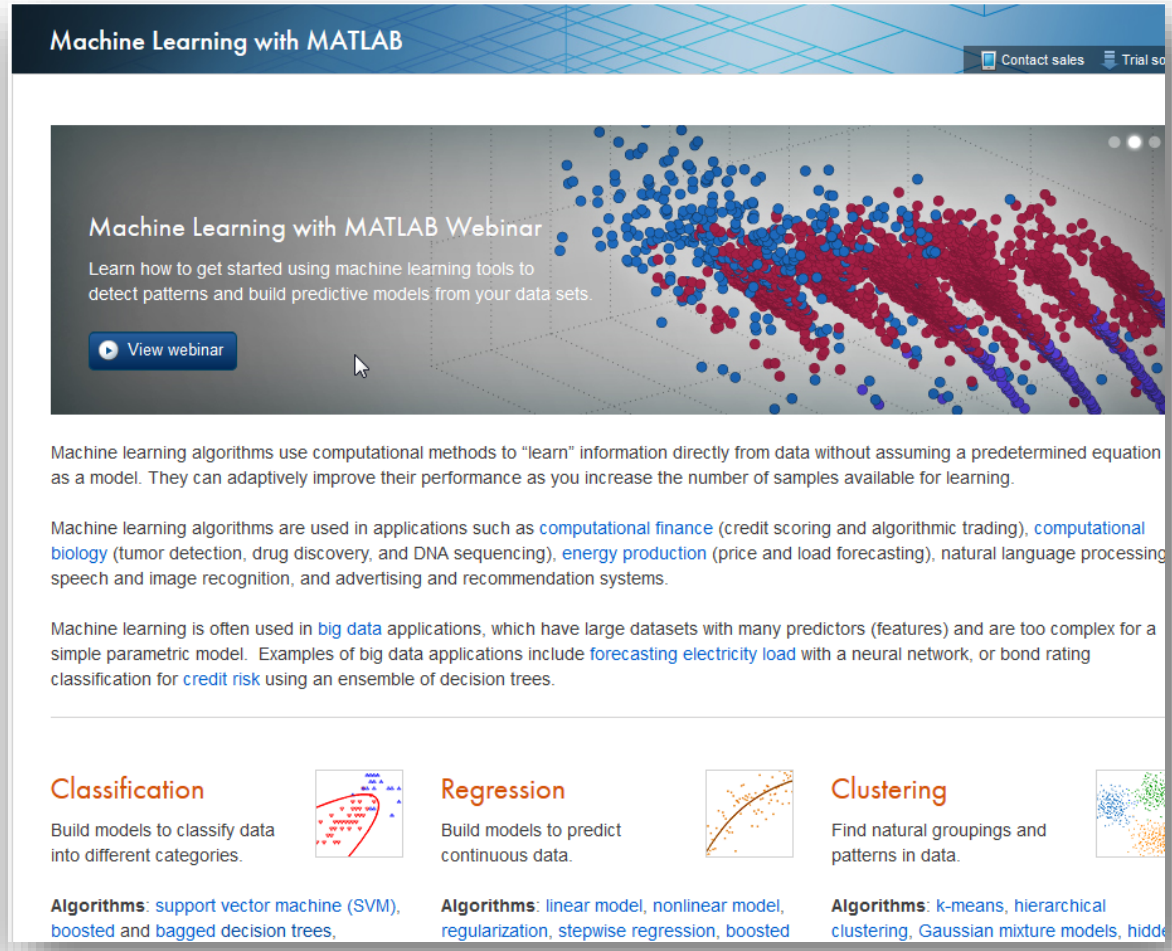


Email me if you have further questions

Additional Resources

Documentation: mathworks.com/machine-learning





Thank You