Modeling, Simulation and Implementation using MATLAB & Simulink

Dhirendra Singh
Application Engineer, MathWorks
dsingh@mathworks.com

Agenda – Day 1

Day 1

09:00 am - 09:30 am	Registration
09:30 am - 09:45 am	Welcome Address
09:45 am -11:00 am	MATLAB and Simulink in Engineering Education MATLAB Basics for the Budding Engineer •Experimentation and Modeling in MATLAB •Design and Implementation •Project-Based Learning (Arduino, RaspberryPi) •Machine Learning & Data Analytics
11:00 am - 11:30 am	Tea Break
11:30 am - 12:30 pm	•Accessing, exploring, analyzing, and visualizing data in MATLAB •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
12:30 pm - 2:30 pm	Lunch Break
02:30 pm - 04:30 pm	•Electrical engineering concepts Using MATLAB and Simulink •System Identification & Neural Network Based System Modeling Techniques •Electrical engineering using Simscape (Physical Modeling) •Electrical engineering using SimPowersystems •Control system design and analysis •What is IoT? • Market Drivers and Challenges • Introduction to ThingSpeak • Examples • Other IoT examples using MW tools • MATLAB and Simulink Capabilities for IoT
04:30 pm - 05:00 pm	Tea Break

Agenda – Day 2

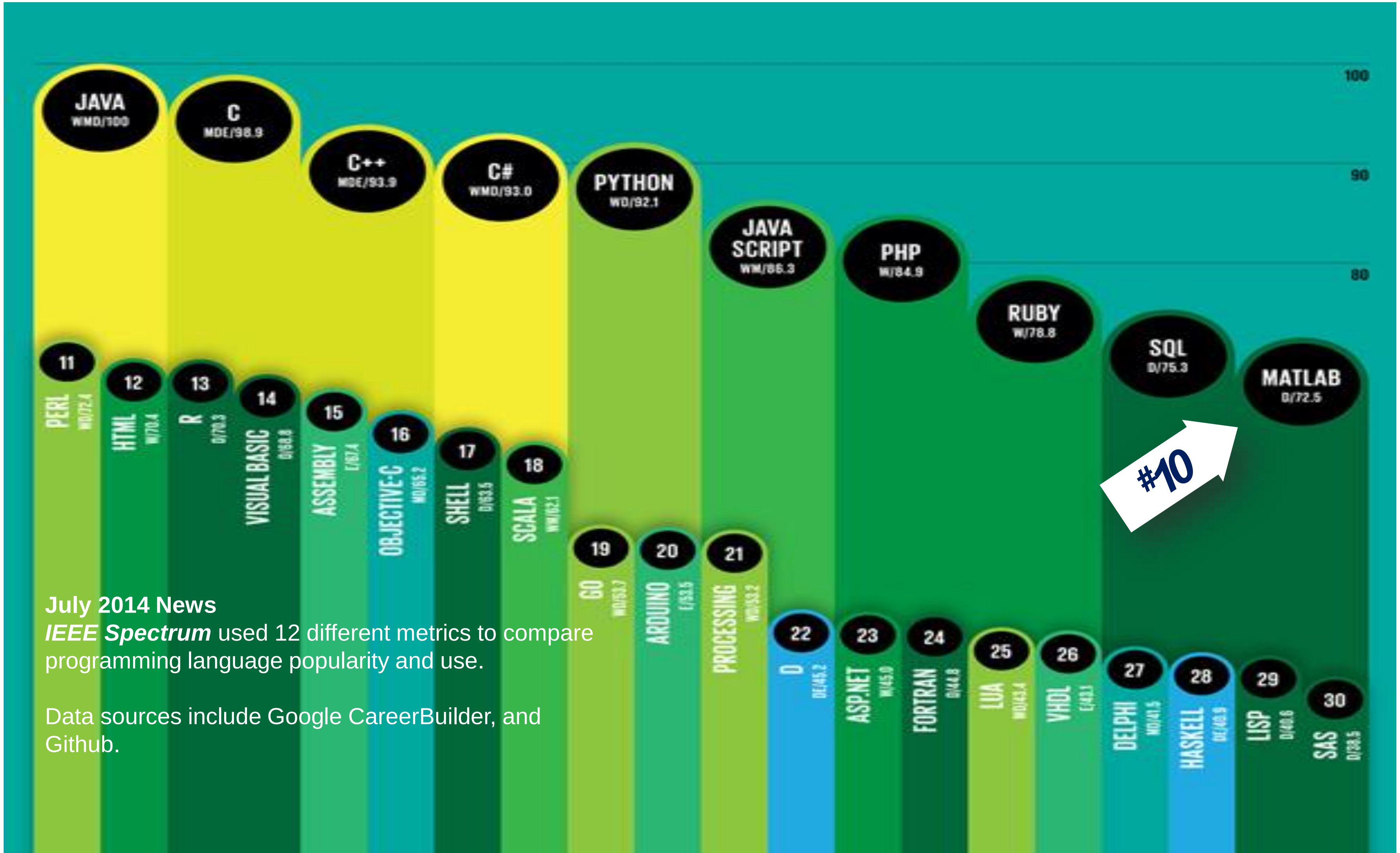
Day 2

10:00 am -11:00 pm	•Mechanical engineering and Control System Concepts Using MATLAB and Simulink. Mechanical engineering concepts using Simscape (Physical Modeling) •Multi-Body Dynamics Simulation using SimMechanics
11:00 am - 11:30 am	Tea Break
11:30 am - 01:00 pm	•Import CAD Models using GetMechanics App •Implement Control on Low cost hardware - Arduino •Demo of Magnetic Levitation System
1:00 pm - 2:00 pm	Lunch Break

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.

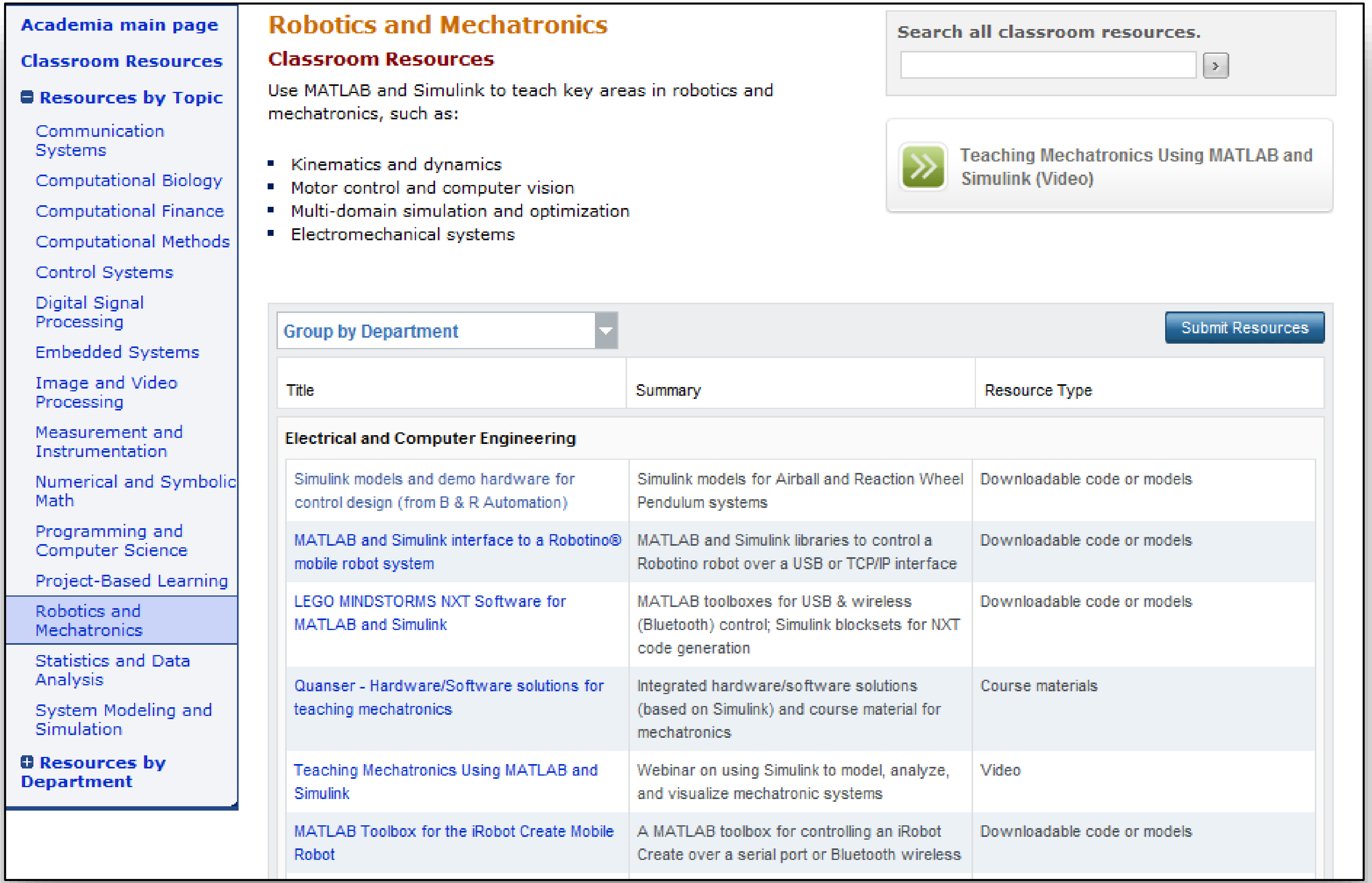
Supporting Innovation

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



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
- Statistics and Data Analysis
- System Modeling and Simulation

Resources by Department

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

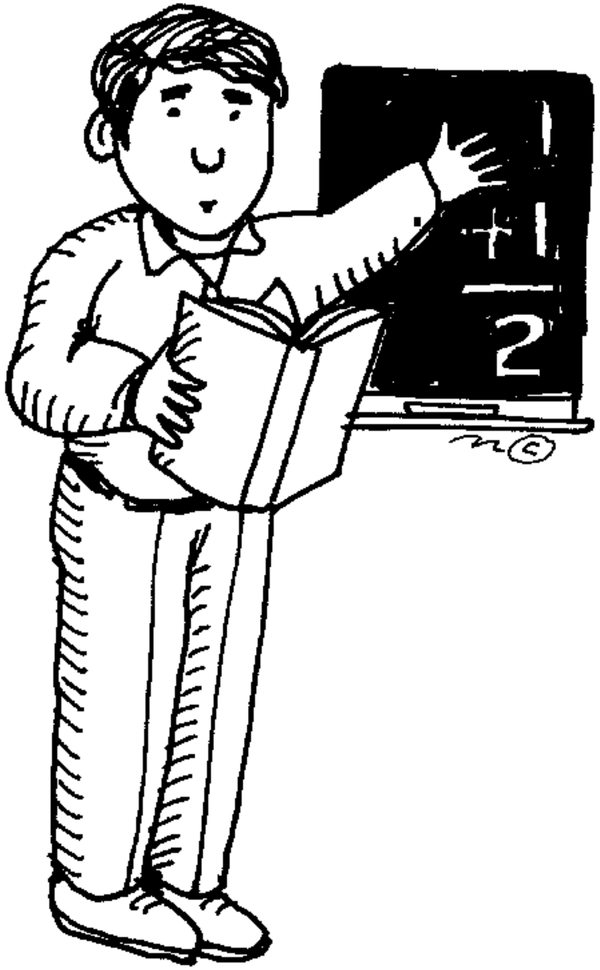
Submit Resources

Title	Summary	Resource Type
Electrical and Computer Engineering		
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

Teacher Activities

- Before a course
  - Define learning objectives
  - Find or write material
  - Decide about teaching forms
  - Decide about examination

- During a course
  - Lectures
  - Practical sessions
  - Question hours
  - Communication with students



Am I addressing all the challenges?

Calculus -

After explaining to a student through various lessons and examples that:

$$\lim_{x \to 8} \frac{1}{x-8} = \infty$$

I tried to check if she really understood that, so I gave her a different example. This was the result:

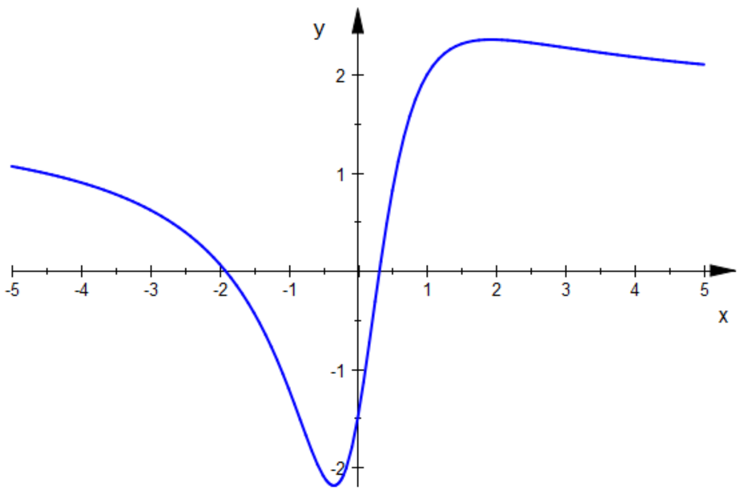
$$\lim_{x \to 5} \frac{1}{x-5} = 5$$

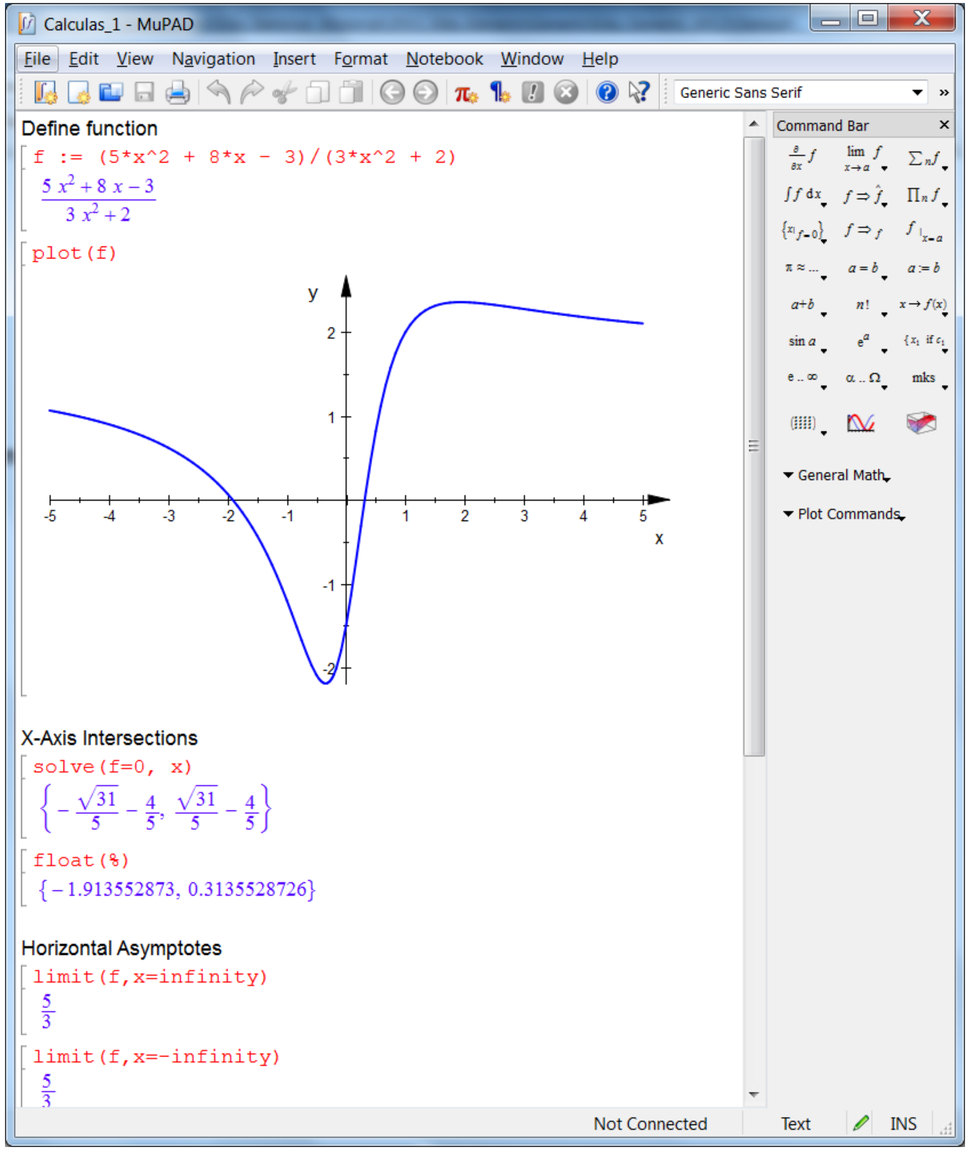
Teaching Calculus – A Symbolic Approach

Problem I:

Find Horizontal Asymptotes and Absolute Maxima and Minima for below function

$$F(x) = \frac{5x^2 + 8x - 3}{3x^2 + 2}$$

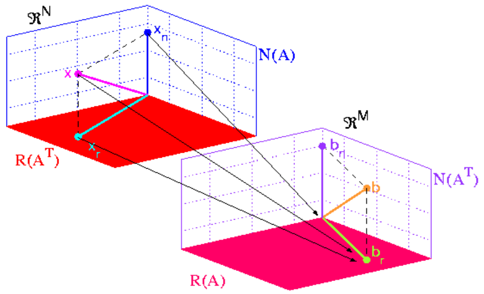




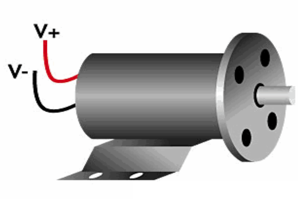
Where is Symbolic Computing Used in Academia?

Anyone applying engineering, scientific, and mathematical principles to *find analytical solutions to technical problems*

- Mathematics departments
  - Foundation courses: Calculus, Differential equations, Linear algebra, …
  - Advanced courses: Number theory, Advanced algebra, …



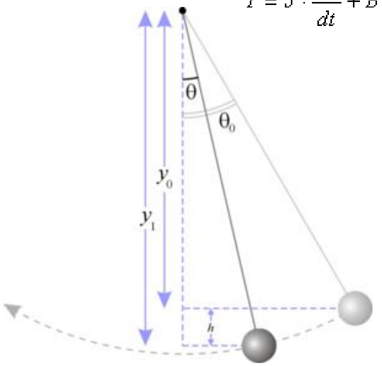
- Engineering departments
  - Mechanical: System dynamics, Heat transfer, Fluid dynamics, …
  - Electrical: Circuit analysis, Signals and systems, …
  - Civil: Solid mechanics, Structural analysis, …



$$V_{AMP} - Vemf = L_M \cdot \frac{dI_1}{dt} + R_M \cdot I_1$$

$$T = J \cdot \frac{d\omega}{dt} + B \cdot \omega$$

- Physics and science departments
  - Physics: Mechanics, Optics, Electromagnetics
  - Life sciences: Bioinformatics, Computational Biology, Systems Biology



Symbolic Math Toolbox Libraries

- Calculus
  - Differentiation
  - Integrals (definite, indefinite)
  - Jacobian
  - Taylor series
  - Limits

Solving Equations
  Algebraic Equations
  Ordinary Differential Equations

- Integral and Z-Transforms
  - Fourier transform
  - Laplace transform
  - Z-transforms

- Simplification
  - Expansion of polynomials
  - Substitution

```
int(exp(-a*x^2),x)
```

$$\frac{\sqrt{\pi}\,\mathrm{erf}(\sqrt{a}\,x)}{2\,\sqrt{a}}$$

```
limit(1/x, x = 0, Left),
limit(1/x, x = 0, Right)
```

$$-\infty, \infty$$

```
transform::fourier(heaviside(t - t0), t, s)
```

$$e^{s\,t0\,i}\left(\pi\,\delta(s)+\frac{i}{s}\right)$$

```
transform::ztrans(sin(k), k, z)
```

$$\frac{z\,\sin(1)}{z^2-2\,\cos(1)\,z+1}$$

```
transform::laplace(1 + exp(-a*t)*sin(b*t), t, s)
```

$$\frac{1}{s}+\frac{b}{(a+s)^2+b^2}$$

```
bernoulli(n, x) $ n = 0..4
```

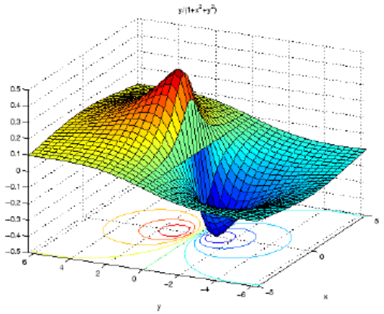
$$1, x-\frac{1}{2}, x^2-x+\frac{1}{6}, x^3-\frac{3\,x^2}{2}+\frac{x}{2}, x^4-2\,x^3+x^2-\frac{1}{30}$$

Linear Algebra
  Operations
  Eigenvalues

- Special Functions
  - Bernoulli, Bessel, Beta, …
  - Fresnel sine/cosine integral, Gamma

Variable Precision Arithmetic

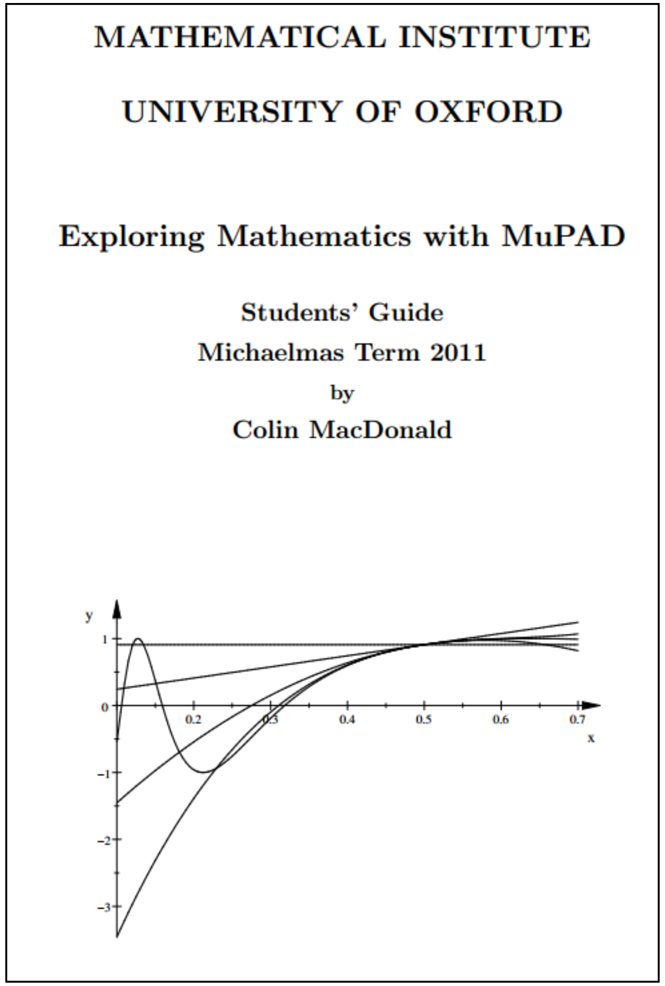
- Plotting
  2-D
  3-D contour, surface, mesh
  Movies



Symbolic Math Toolbox Use in Curriculum
“Exploring Mathematics with MuPad” Course

- Course developed by Dr. Catherine Wilkins (University of Oxford)

- 56 page reference document on getting started with MuPAD notebook interface


MATHEMATICAL INSTITUTE

UNIVERSITY OF OXFORD

Exploring Mathematics with MuPAD

Students’ Guide

Michaelmas Term 2011

by

Colin MacDonald

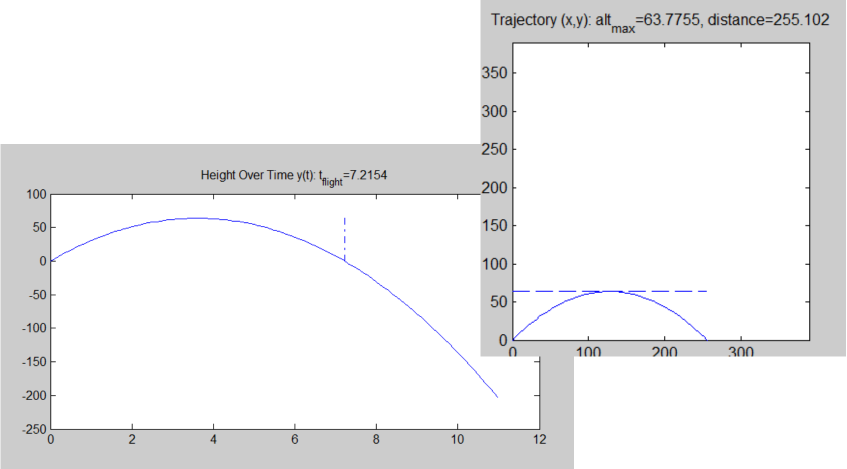
Teaching Math – An Interactive Approach

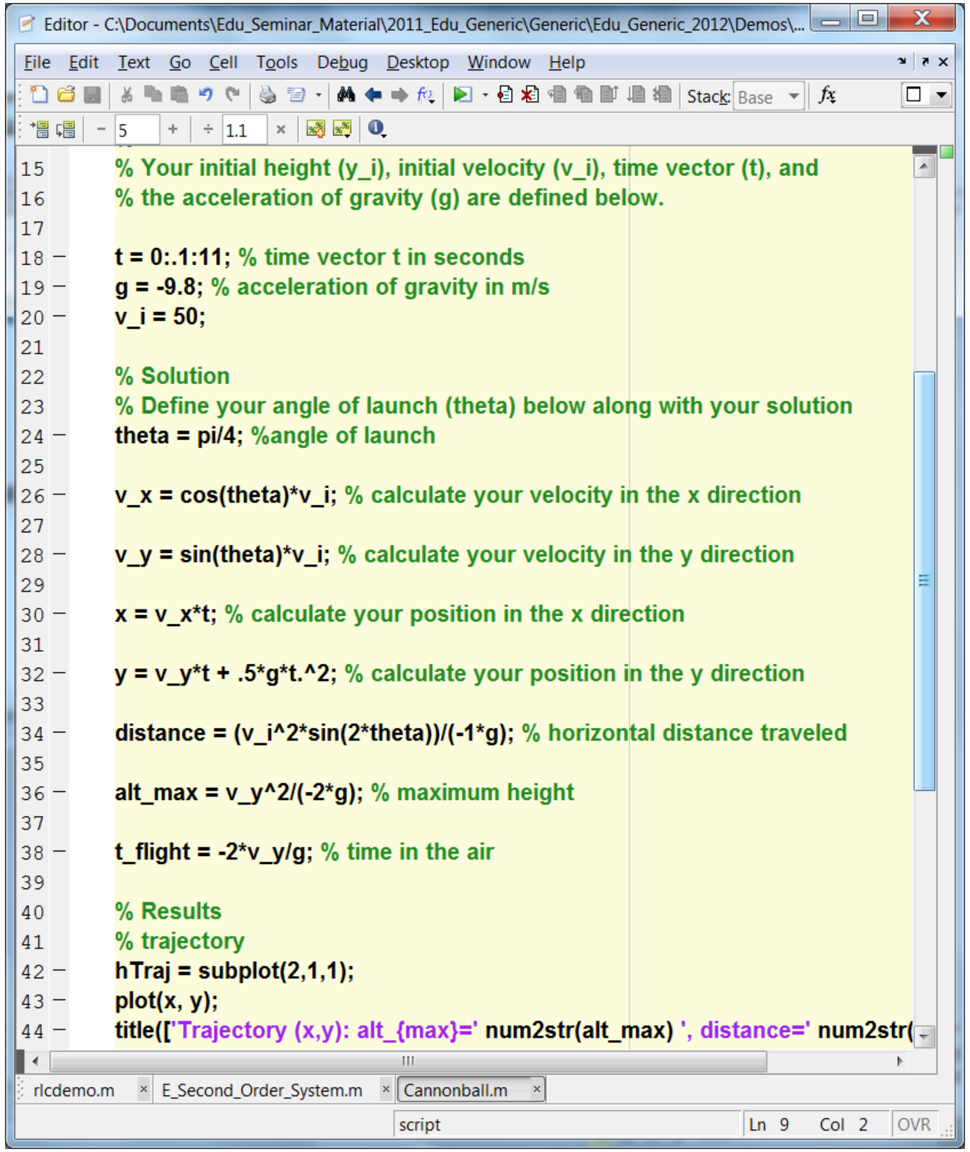
Problem II:

You have been launched as a human cannonball from ground level at an initial velocity (v_i) of 50 m/s at an angle theta.

- How high do you go before falling back down?
- How long where you in the air?

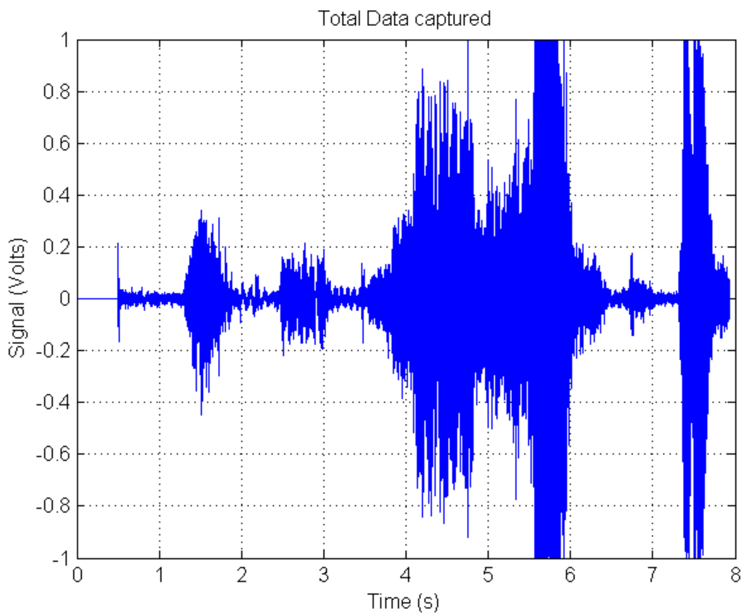
$$Position\_Y = \frac{v_y^2 \sin(2\theta)}{-g}$$



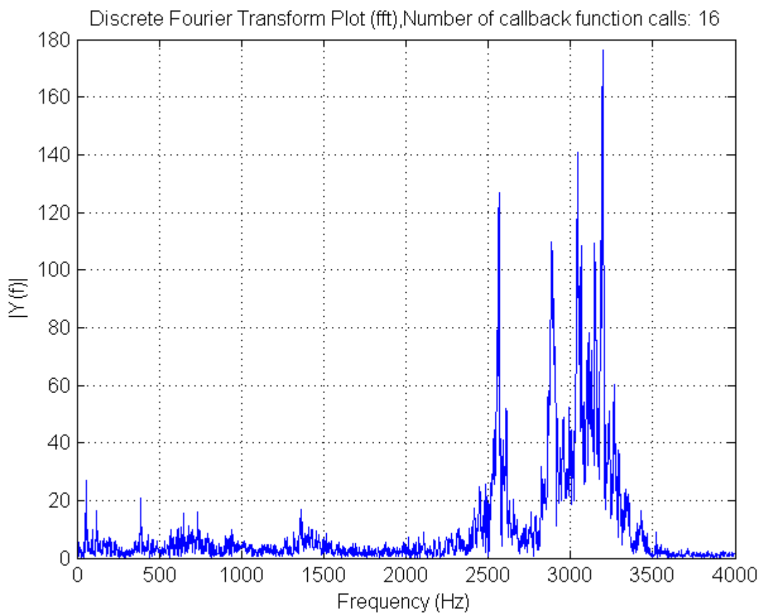


Experimenting with Live Signals

- Acquire live signals from sensors, oscilloscopes and instruments
- Perform analysis and experiments on live data



Live Acquisition of Your Own Voice



Perform Discrete Fourier Transform

MATLAB Connects to Your Hardware Devices

Instrument Control Toolbox
Instruments and RS-232 serial devices

Data Acquisition Toolbox
Plug-in data acquisition devices and sound cards

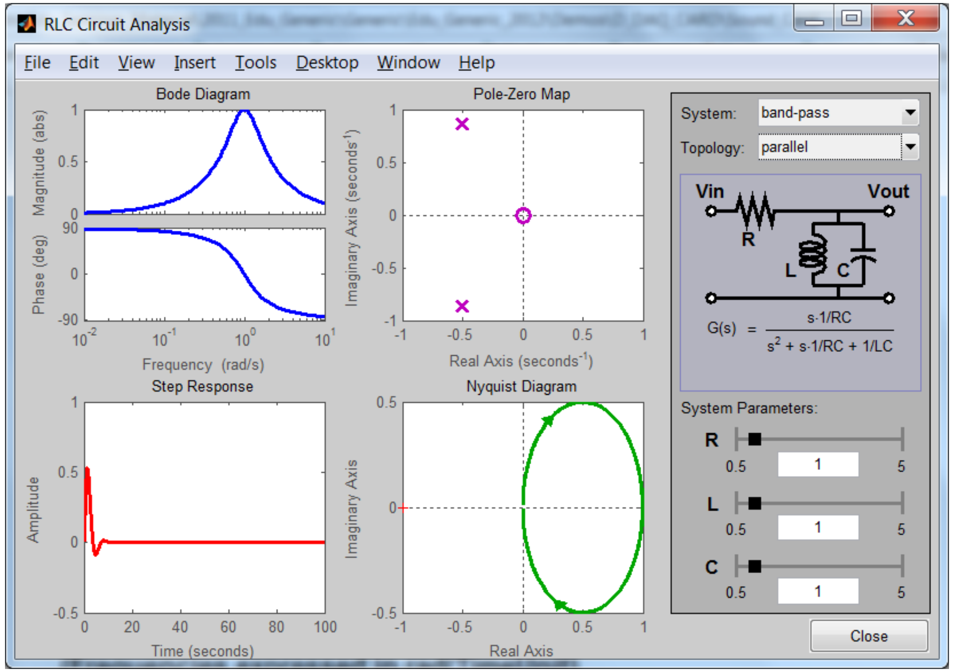
Image Acquisition Toolbox
Image capture devices

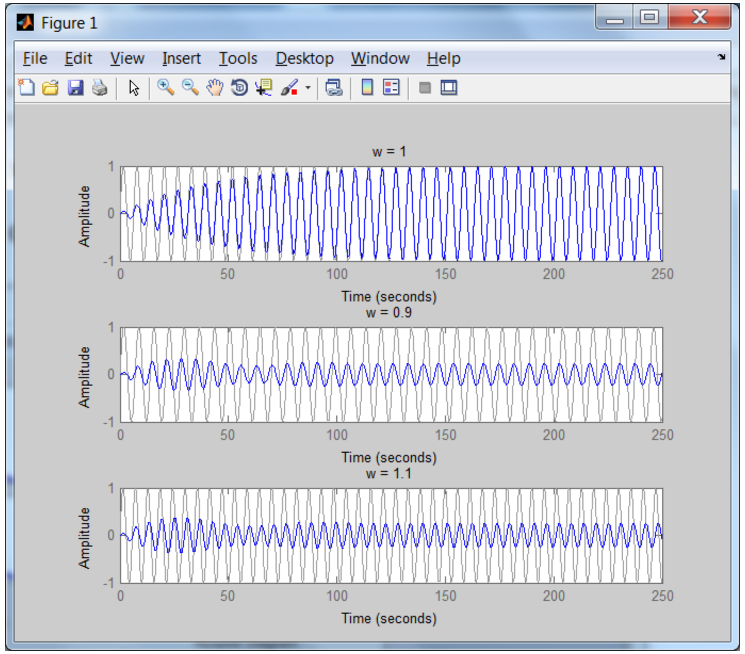
Vehicle Network Toolbox
Vector & Kvaser CAN bus interface devices

MATLAB
Interfaces for communicating with everything

Learning Beyond Classroom

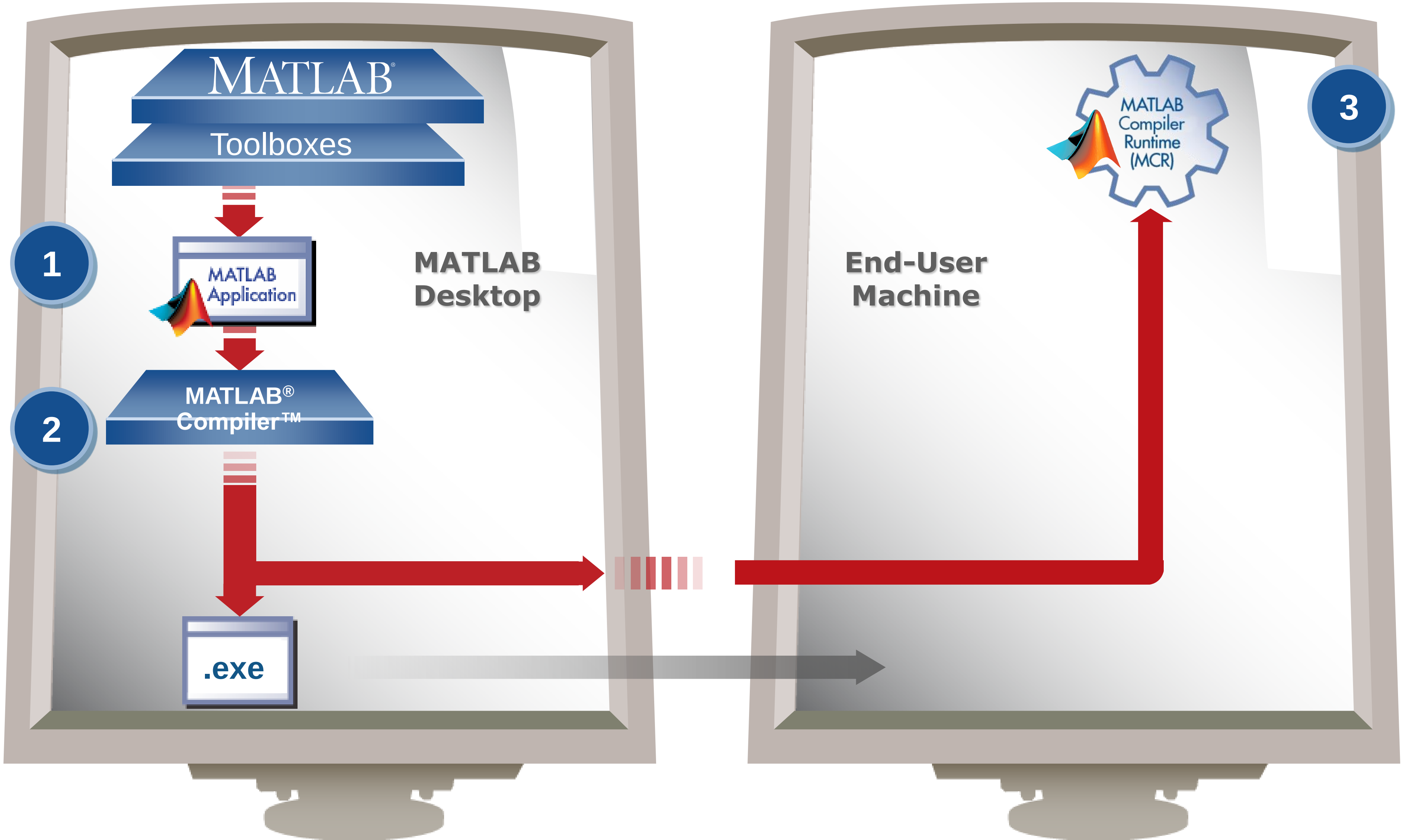
- Design interactive examples to explore what-if scenarios
- Share examples as GUI executable with students





>> rlcdemo

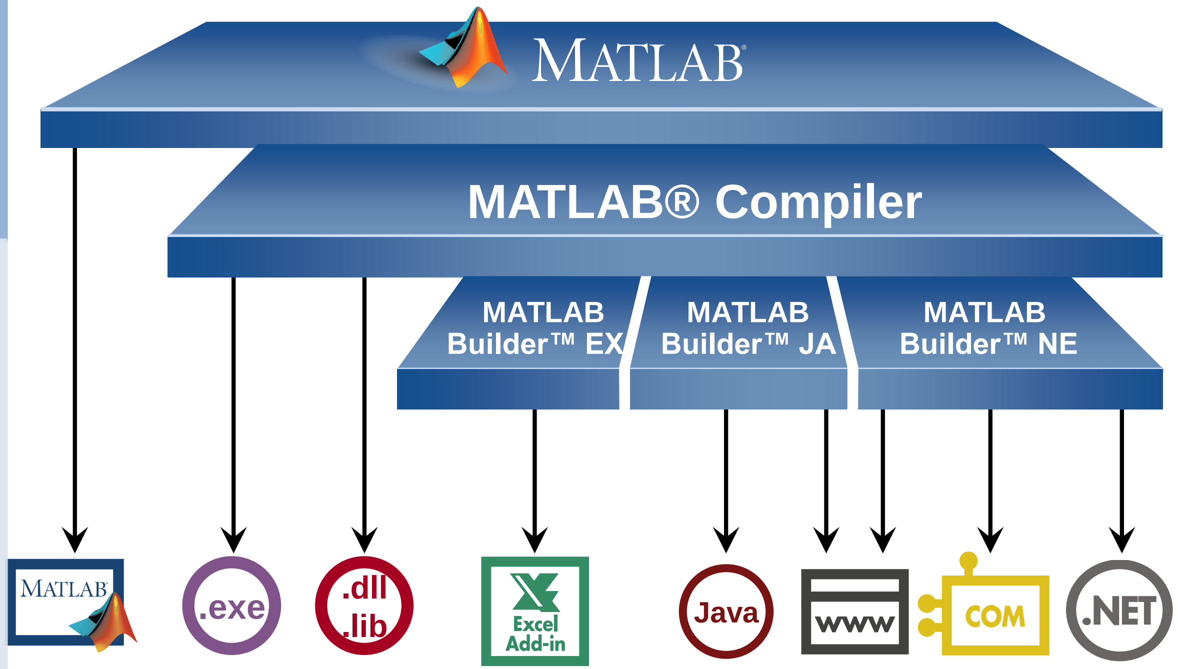
Deploying Applications with MATLAB®



Deploying Applications with MATLAB

Give MATLAB code to students and other faculties who do not have MATLAB

- Use MATLAB Compiler to create stand-alone executable and shared libraries
- Use Compiler add-ons to create software components



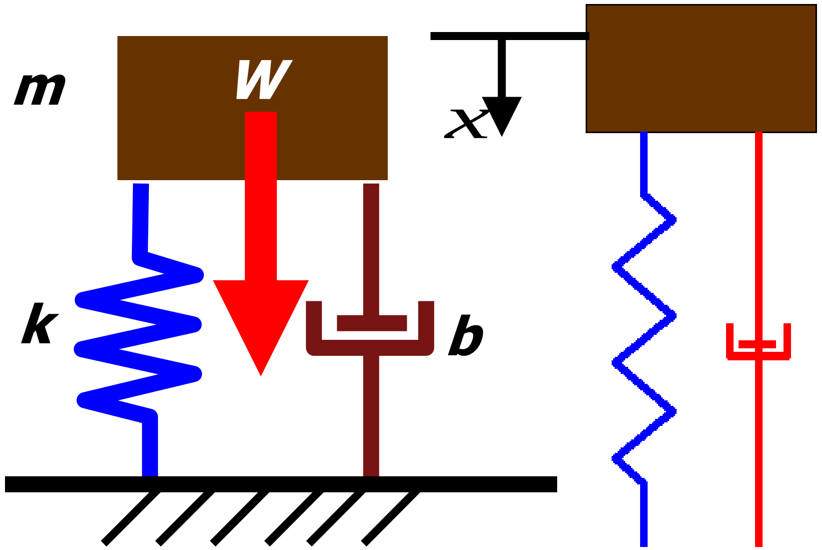
Agenda – Day 1

Day 1

09:00 am - 09:30 am	Registration
09:30 am - 09:45 am	Welcome Address
09:45 am -11:00 am	MATLAB and Simulink in Engineering Education MATLAB Basics for the Budding Engineer •Experimentation and Modeling in MATLAB •Design and Implementation •Project-Based Learning (Arduino, RaspberryPi) •Machine Learning & Data Analytics
11:00 am - 11:30 am	Tea Break
11:30 am - 12:30 pm	•Accessing, exploring, analyzing, and visualizing data in MATLAB •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
12:30 pm - 2:30 pm	Lunch Break
02:30 pm - 04:30 pm	•Electrical engineering concepts Using MATLAB and Simulink •System Identification & Neural Network Based System Modeling Techniques •Electrical engineering using Simscape (Physical Modeling) •Electrical engineering using SimPowersystems •Control system design and analysis •What is IoT? • Market Drivers and Challenges • Introduction to ThingSpeak • Examples • Other IoT examples using MW tools • MATLAB and Simulink Capabilities for IoT
04:30 pm - 05:00 pm	Tea Break

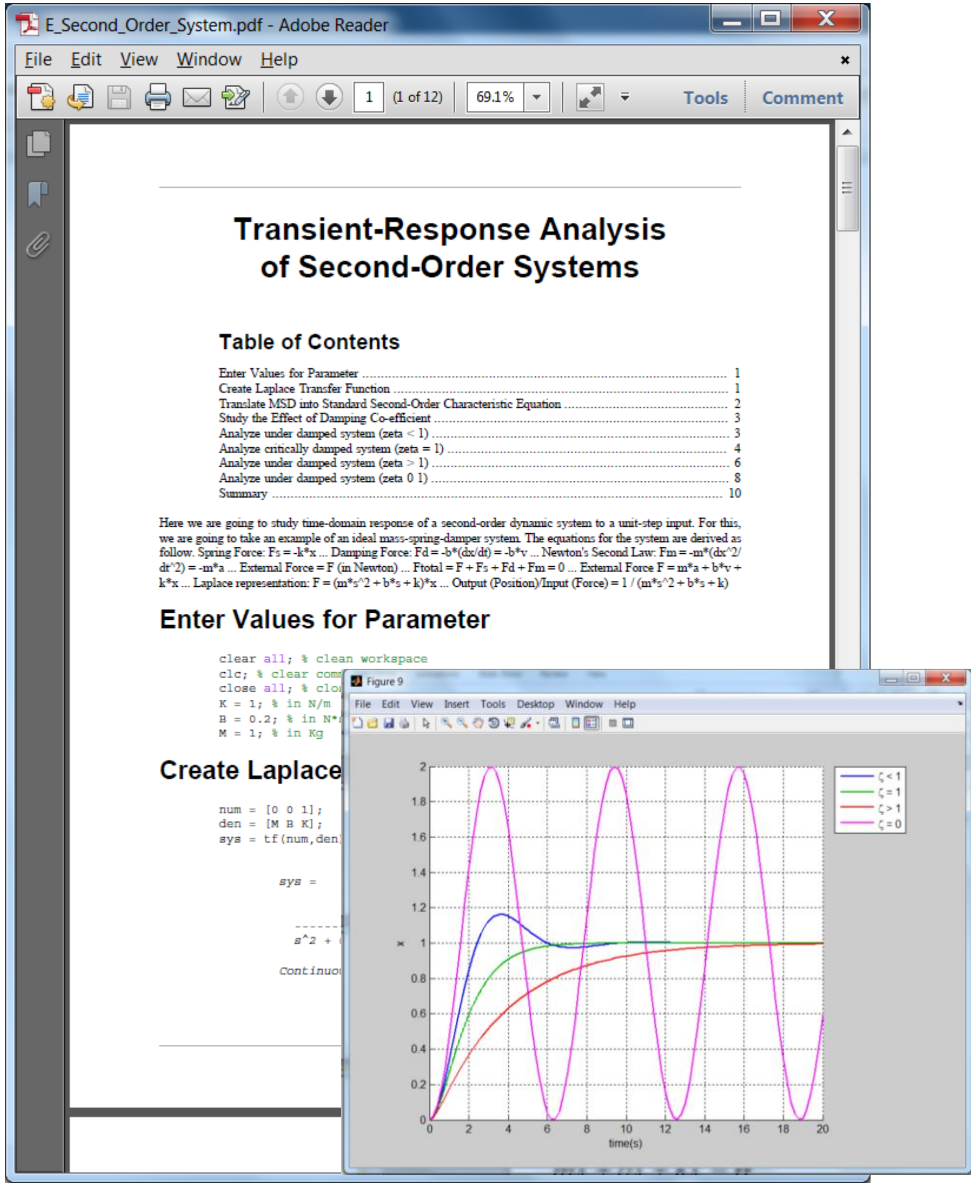
Making Classroom Notes Living Documents

- Example: Stability Analysis of Second Order Systems



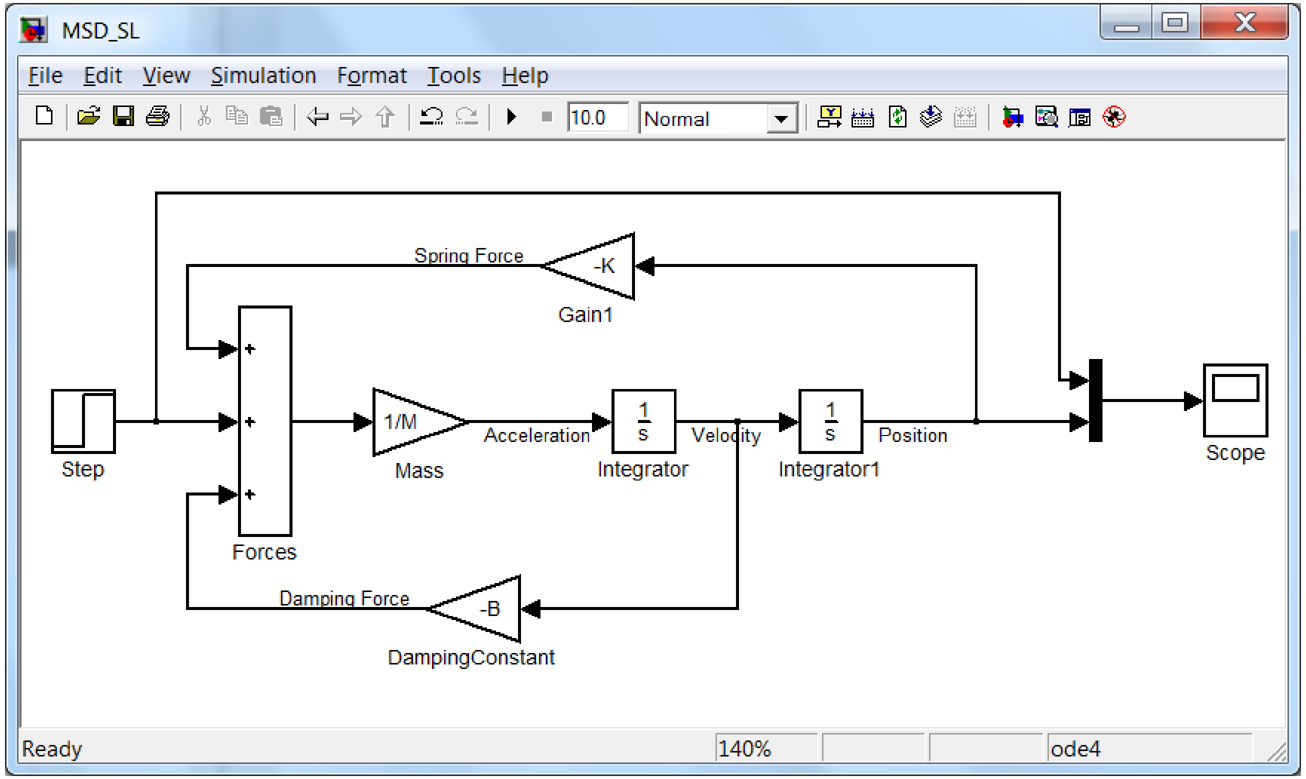
$$m\ddot{x} + b\dot{x} + kx = W$$

Mass-Spring-Damper System

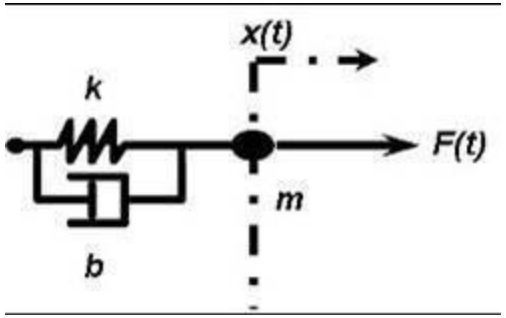


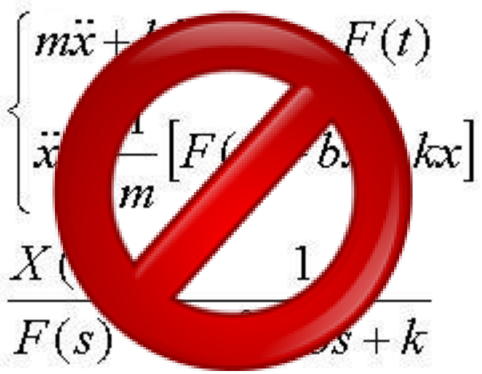
Design and Analysis with Simulink

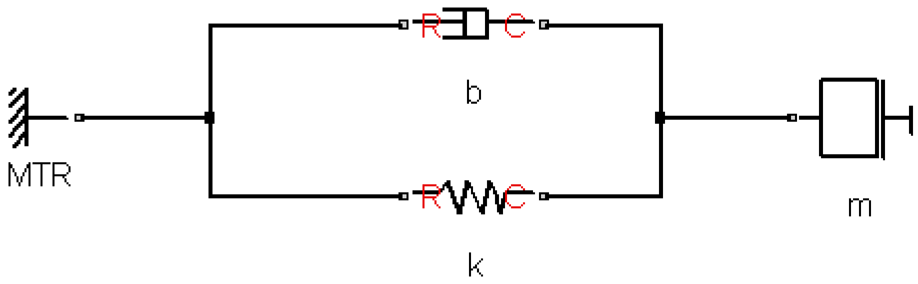
- Introduce blocks, (libraries), how to make a model
- Hybrid systems - continuous and discrete components
- Time-driven simulation of system model
- Intuitive representation of a system



Teaching Multi-Domain Systems using Simscape™







Let Students Explore More

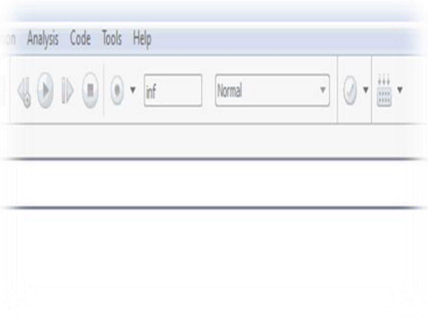
“It's not that I'm very smart;
I am only passionately curious and
it's just that I stay with problems longer.”

-- Albert Einstein, Theoretical Physicist

- Interactive tools allows students to explore more and stay with problem longer.

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

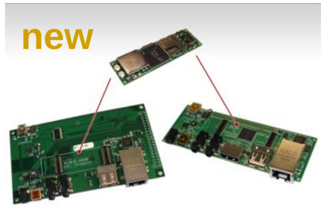
BeagleBoard

PandaBoard

Arduino®

LEGO® MINDSTORMS® NXT

Gumstix® Overo®

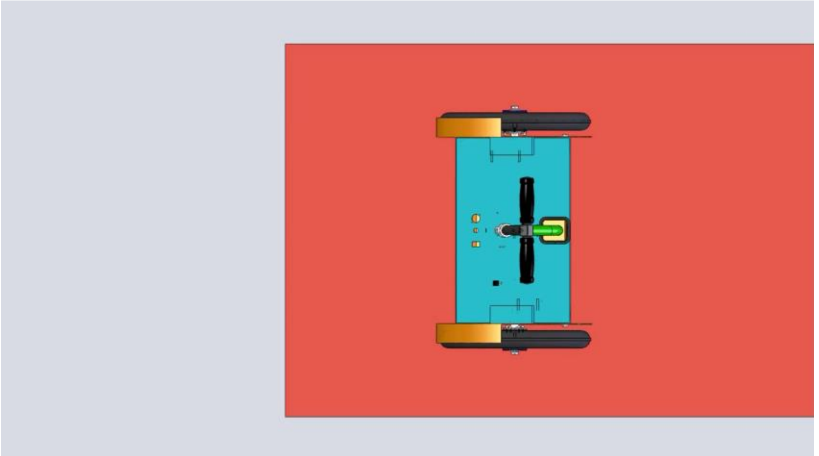


Raspberry Pi ®

new

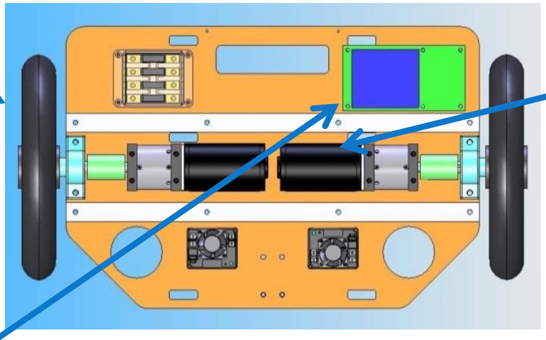
Demo

How it Works

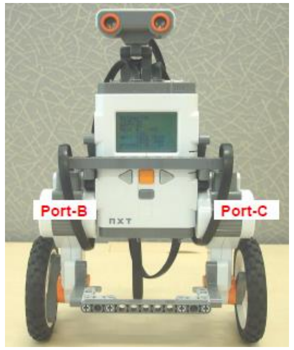


Wheels

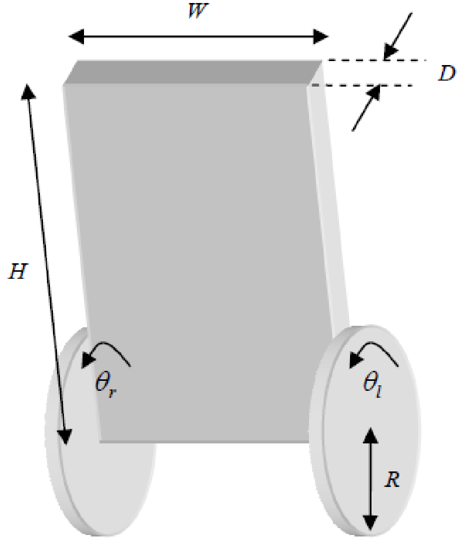
Motor

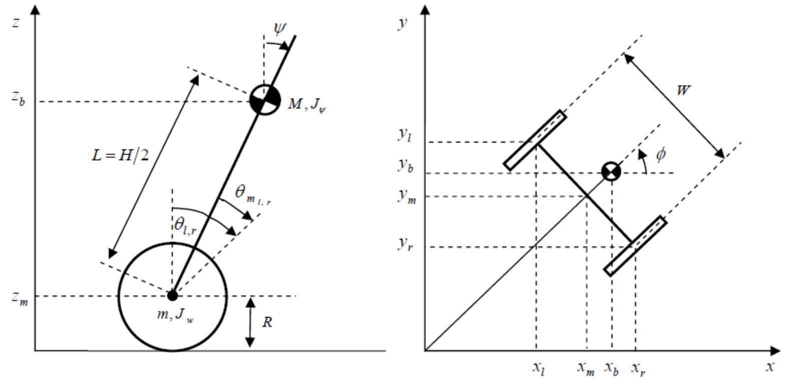


Gyro Sensor

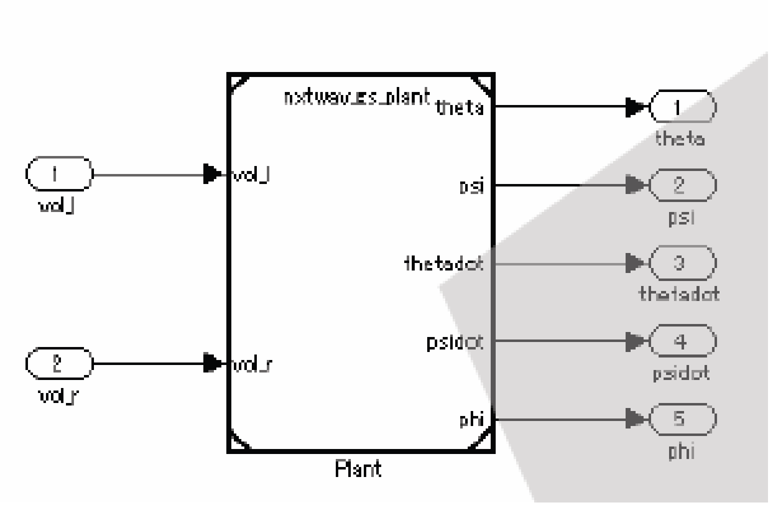


Modeling the Segway Dynamics





ψ : body pitch angle $\theta_{l,r}$: wheel angle (l, r indicates left and right) $\theta_{m_{l,r}}$: DC motor angle



Motion Equations of Two-Wheeled Inverted Pendulum

$$T_1 = \frac{1}{2}m\left(\dot{x}_l^2 + \dot{y}_l^2 + \dot{z}_l^2\right) + \frac{1}{2}m\left(\dot{x}_r^2 + \dot{y}_r^2 + \dot{z}_r^2\right) + \frac{1}{2}M\left(\dot{x}_b^2 + \dot{y}_b^2 + \dot{z}_b^2\right)$$

$$T_2 = \frac{1}{2}J_w\dot{\theta}_l^2 + \frac{1}{2}J_w\dot{\theta}_r^2 + \frac{1}{2}J_\psi\dot{\psi}^2 + \frac{1}{2}J_\phi\dot{\phi}^2 + \frac{1}{2}n^2J_m(\dot{\theta}_l - \dot{\psi})^2 + \frac{1}{2}n^2J_m(\dot{\theta}_r - \dot{\psi})^2$$

$$U = mgz_l + mgz_r + Mgz_b$$

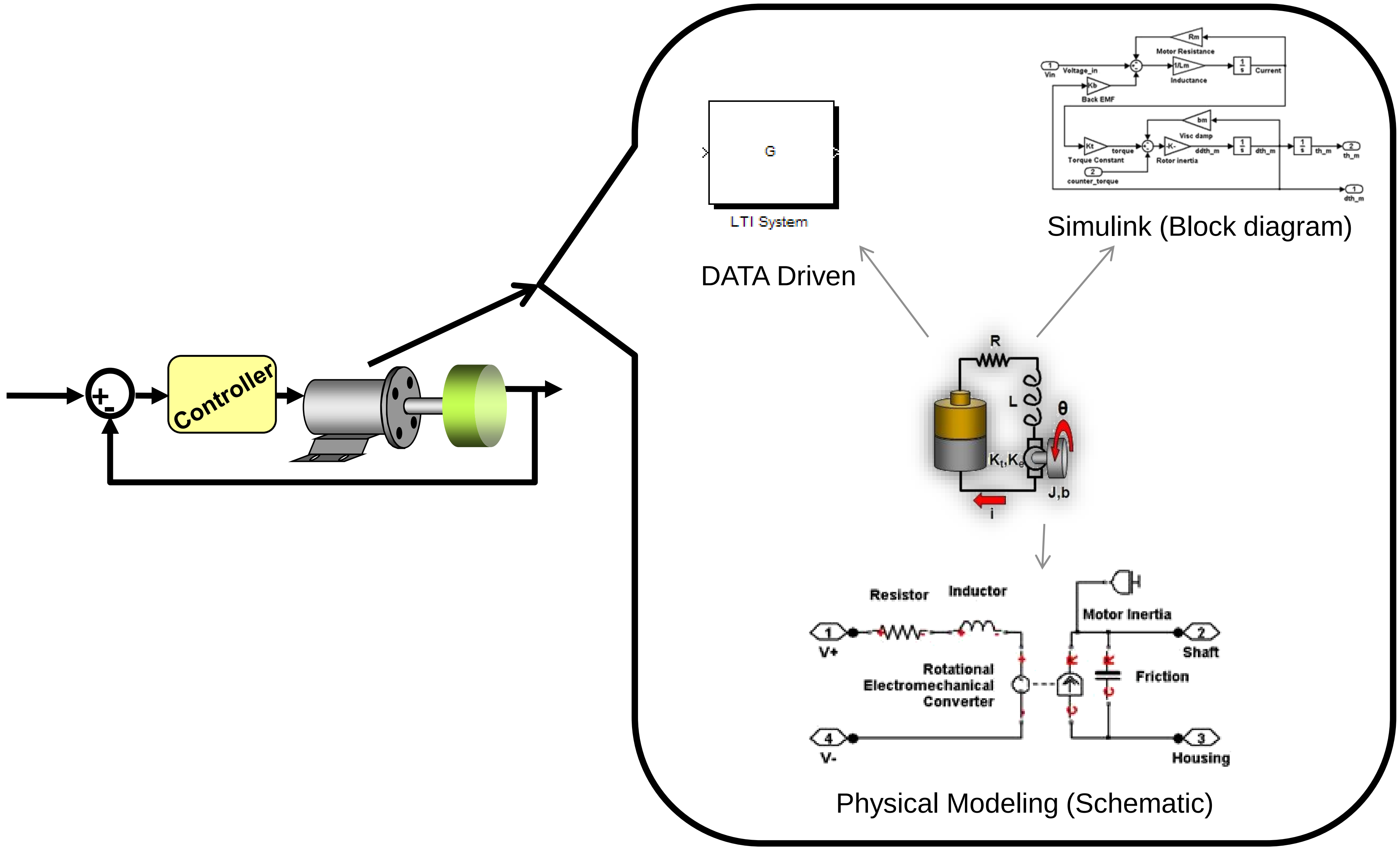
$$L = T_1 + T_2 - U$$

Lagrange equations are the following

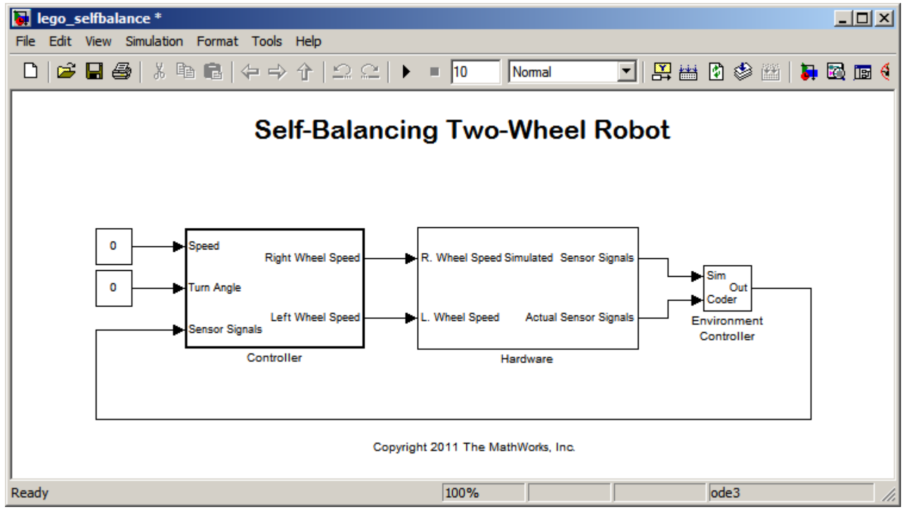
$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\theta}}\right) - \frac{\partial L}{\partial \theta} = F_\theta \qquad \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\phi}}\right) - \frac{\partial L}{\partial \phi} = F_\phi$$

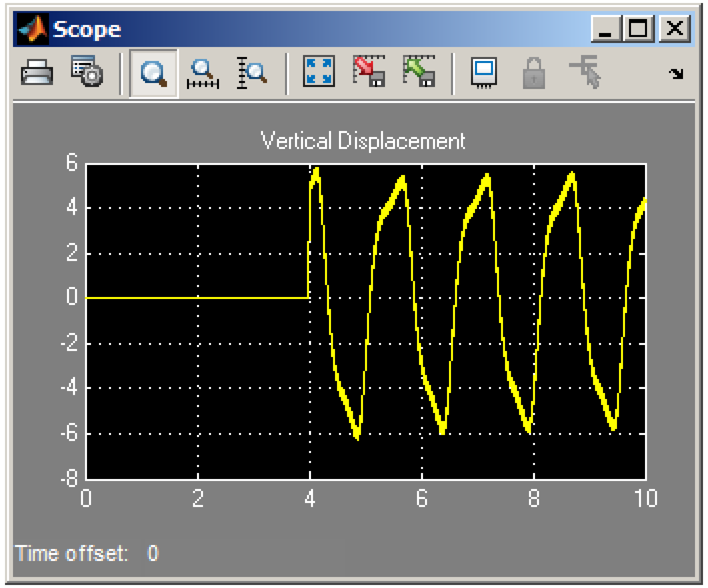
$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\psi}}\right) - \frac{\partial L}{\partial \psi} = F_\psi$$

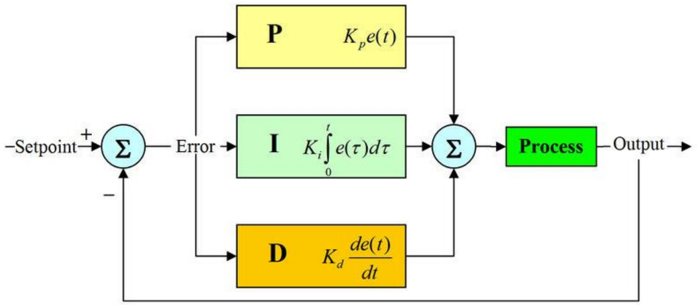
Different modeling approaches



Modeling the Controller



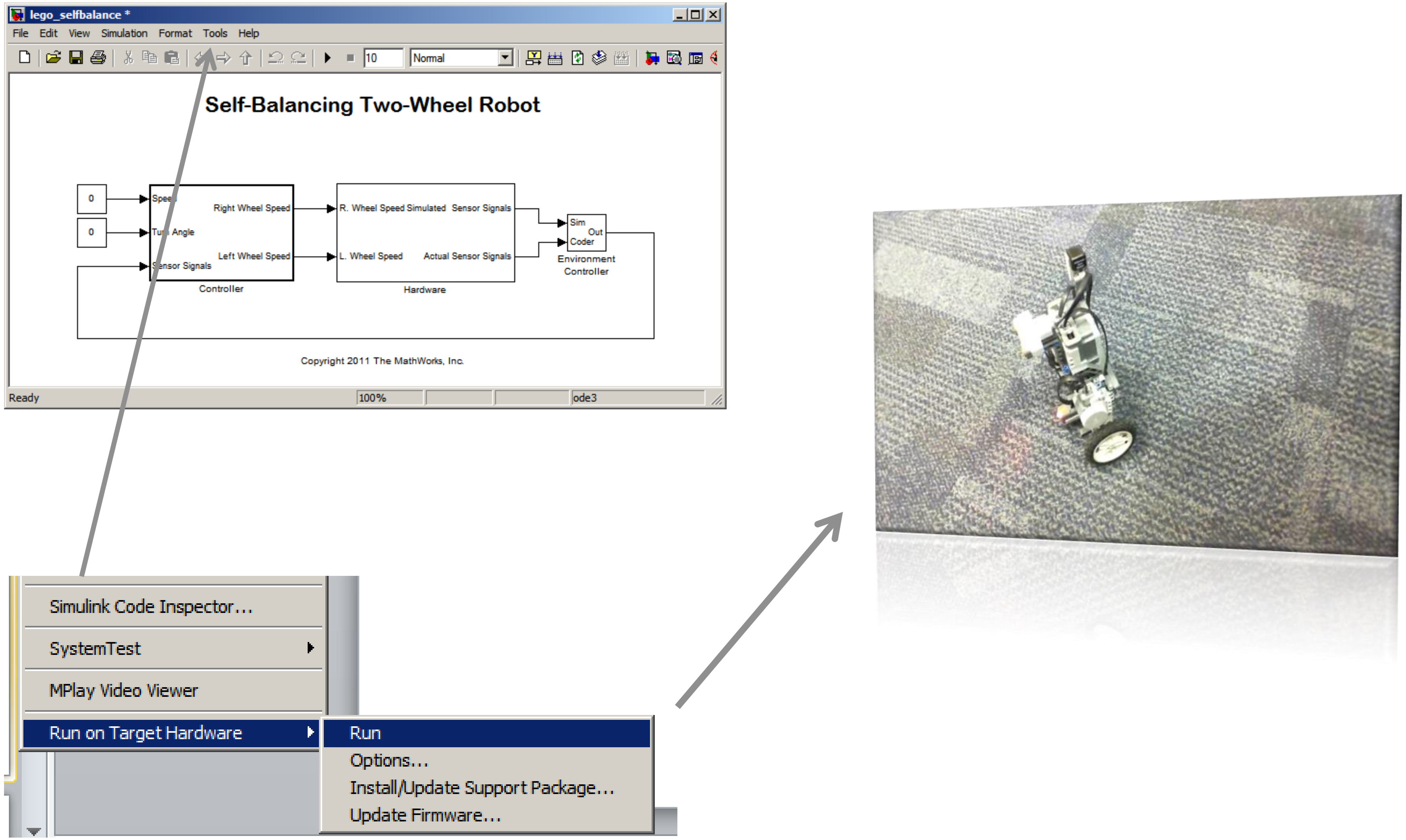




PID

- 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

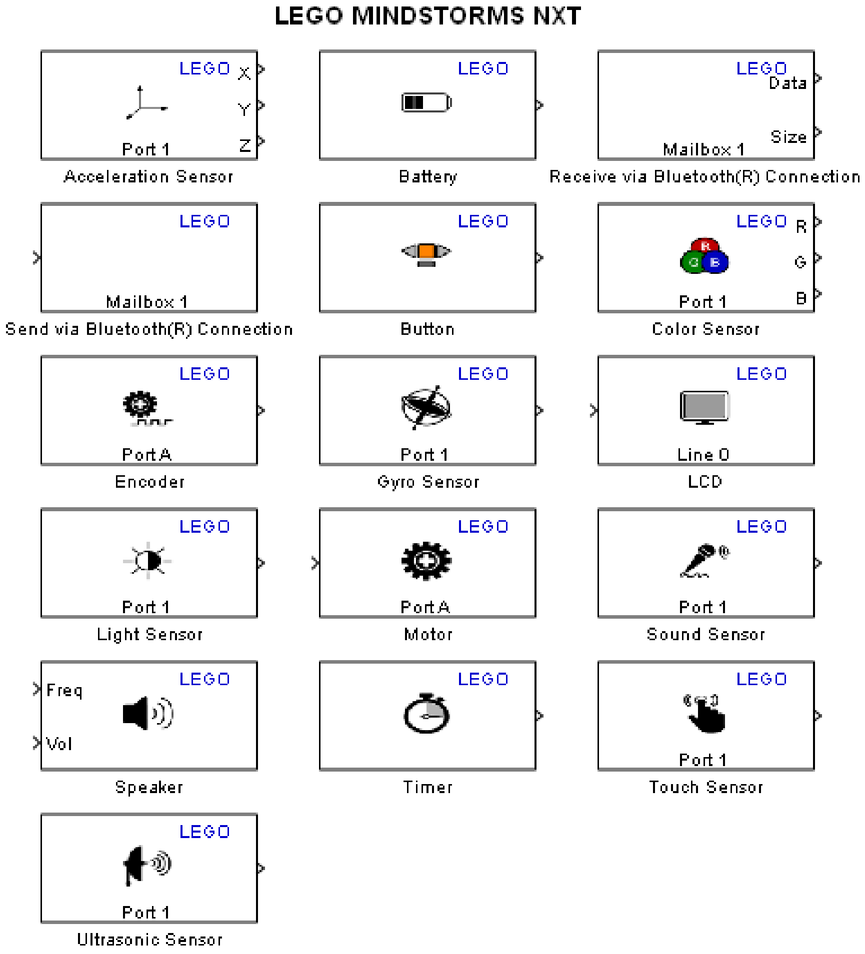
Testing the Controller

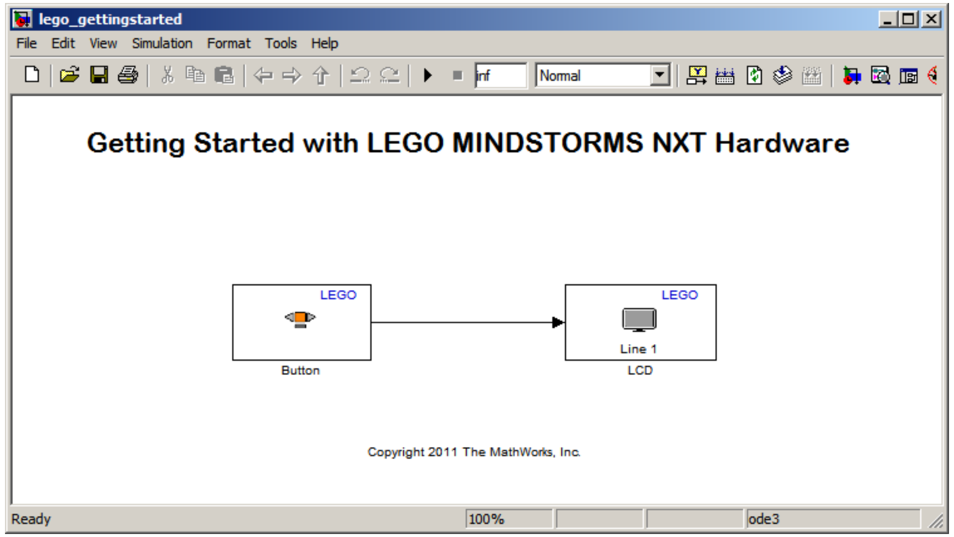


What our tools offer?

- **Simulink solution**
  - Real-Time Toolbox for LEGO Platform enables you to execute Simulink® and Stateflow® models on a LEGO MINDSTORMS hardware platform for rapid control prototyping
  - hardware-in-the-loop (HIL) simulation, and other real-time applications
  - library of I/O device drivers for LEGO MINDSTORMS sensors and actuators, a real-time kernel, and an interface for real-time monitoring, parameter tuning, and data logging.

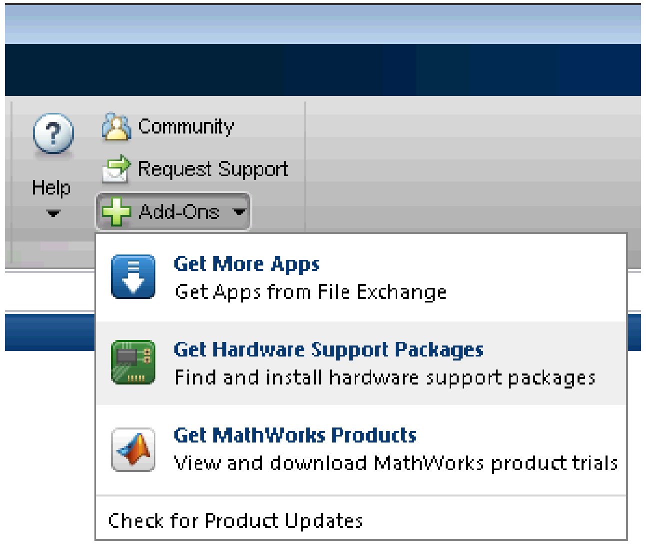
LEGO MINDSTORMS NXT Block Library

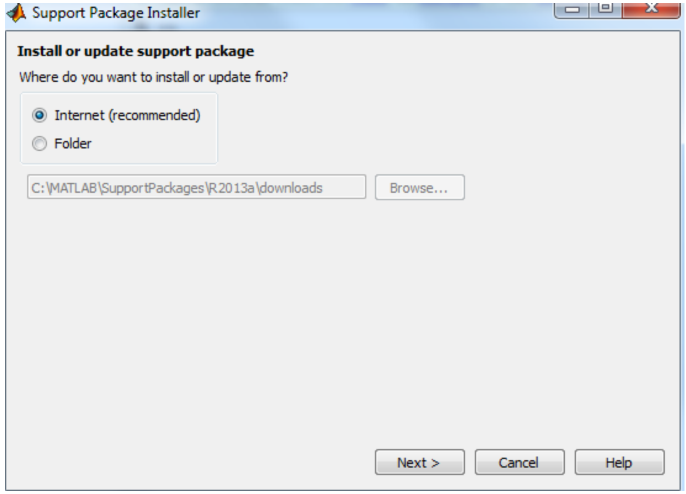


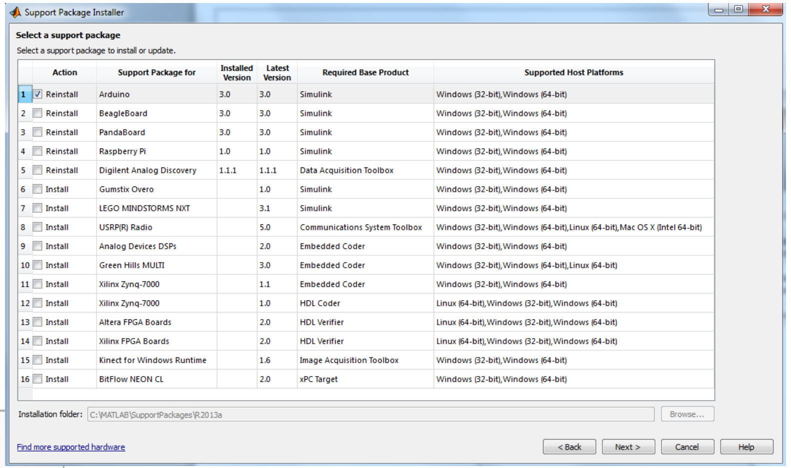


Installing Target Library

Get from the MATLAB Toolstrip: Add-Ons → Get Hardware Support Packages






Support Package Installer

Select a support package

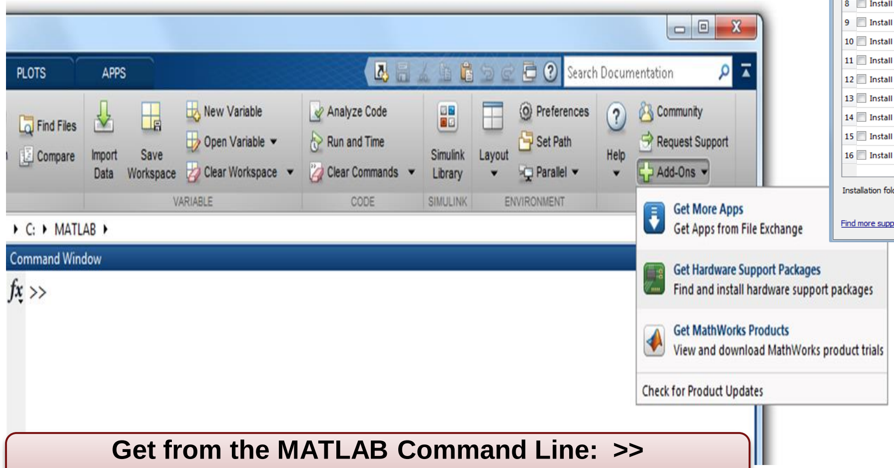
Select a support package to install or update.

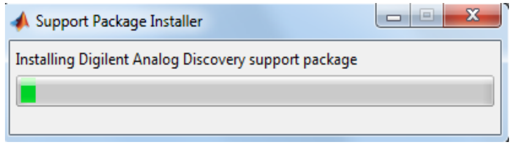
	Action	Support Package for	Installed Version	Latest Version	Required Base Product	Supported Host Platforms
1	Reinstall	Arduino	3.0	3.0	Simulink	Windows (32-bit),Windows (64-bit)
2	Reinstall	BeagleBoard	3.0	3.0	Simulink	Windows (32-bit),Windows (64-bit)
3	Reinstall	PandaBoard	3.0	3.0	Simulink	Windows (32-bit),Windows (64-bit)
4	Reinstall	Raspberry Pi	1.0	1.0	Simulink	Windows (32-bit),Windows (64-bit)
5	Reinstall	Digilent Analog Discovery	1.1.1	1.1.1	Data Acquisition Toolbox	Windows (32-bit),Windows (64-bit)
6	Install	Gumstix Overo		1.0	Simulink	Windows (32-bit),Windows (64-bit)
7	Install	LEGO MINDSTORMS NXT		3.1	Simulink	Windows (32-bit),Windows (64-bit)
8	Install	USRP(R) Radio		5.0	Communications System Toolbox	Windows (32-bit),Windows (64-bit),Linux (64-bit),Mac OS X (Intel 64-bit)
9	Install	Analog Devices DSPs		2.0	Embedded Coder	Windows (32-bit),Windows (64-bit)
10	Install	Green Hills MULTI		3.0	Embedded Coder	Windows (32-bit),Windows (64-bit),Linux (64-bit)
11	Install	Xilinx Zynq-7000		1.1	Embedded Coder	Windows (32-bit),Windows (64-bit)
12	Install	Xilinx Zynq-7000		1.0	HDL Coder	Linux (64-bit),Windows (32-bit),Windows (64-bit)
13	Install	Altera FPGA Boards		2.0	HDL Verifier	Linux (64-bit),Windows (32-bit),Windows (64-bit)
14	Install	Xilinx FPGA Boards		2.0	HDL Verifier	Linux (64-bit),Windows (32-bit),Windows (64-bit)
15	Install	Kinect for Windows Runtime		1.6	Image Acquisition Toolbox	Windows (32-bit),Windows (64-bit)
16	Install	BitFlow NEON CL		2.0	xPC Target	Windows (32-bit),Windows (64-bit)

Installation folder: C:\MATLAB\SupportPackages\R2013a Browse...

Find more supported hardware

< Back | Next > | Cancel | Help



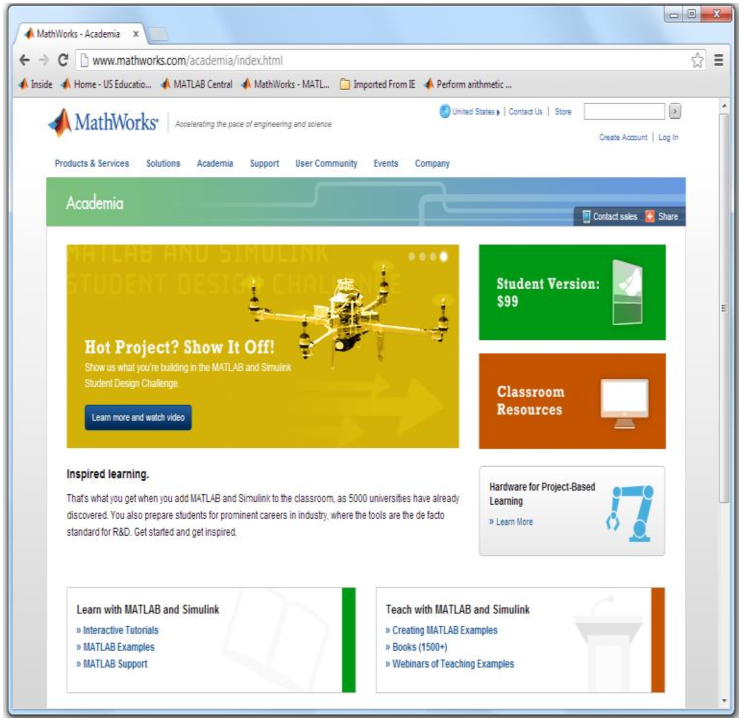


Get from the MATLAB Command Line: >> targetinstaller

Additional Resources

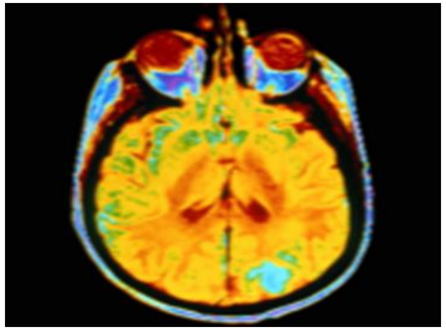
www.mathworks.com/academia

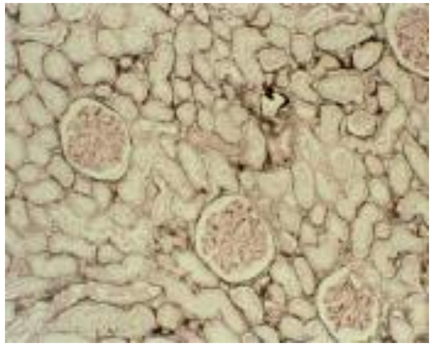
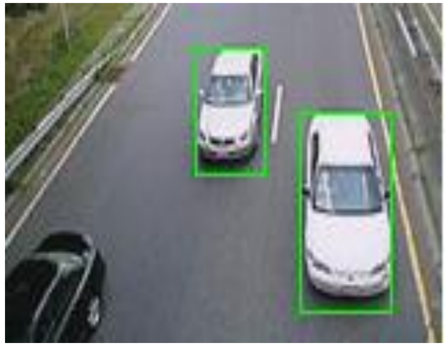
http://www.mathworks.com/hardware-support



Machine Learning is Everywhere

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

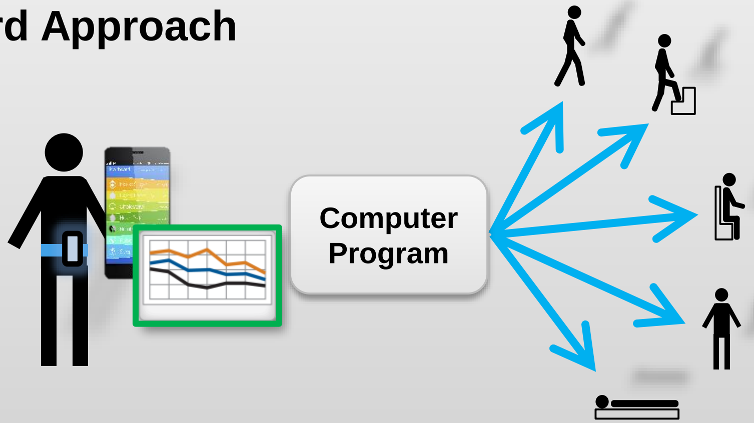


Machine Learning

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

Task: Human Activity Detection

Standard Approach



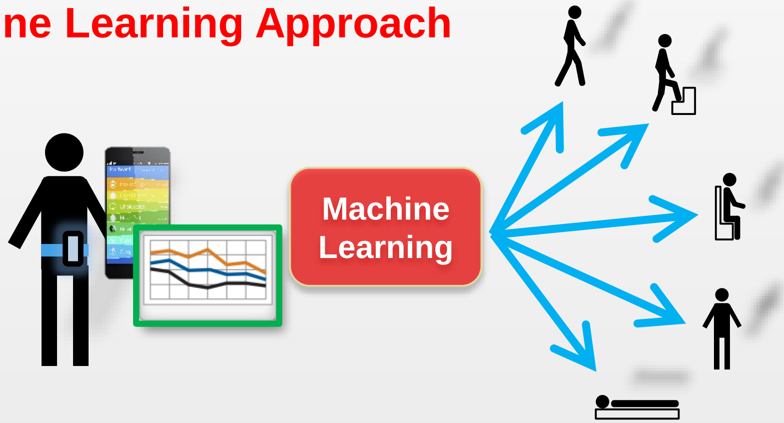
Hand Written Program

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

Formula or Equation

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

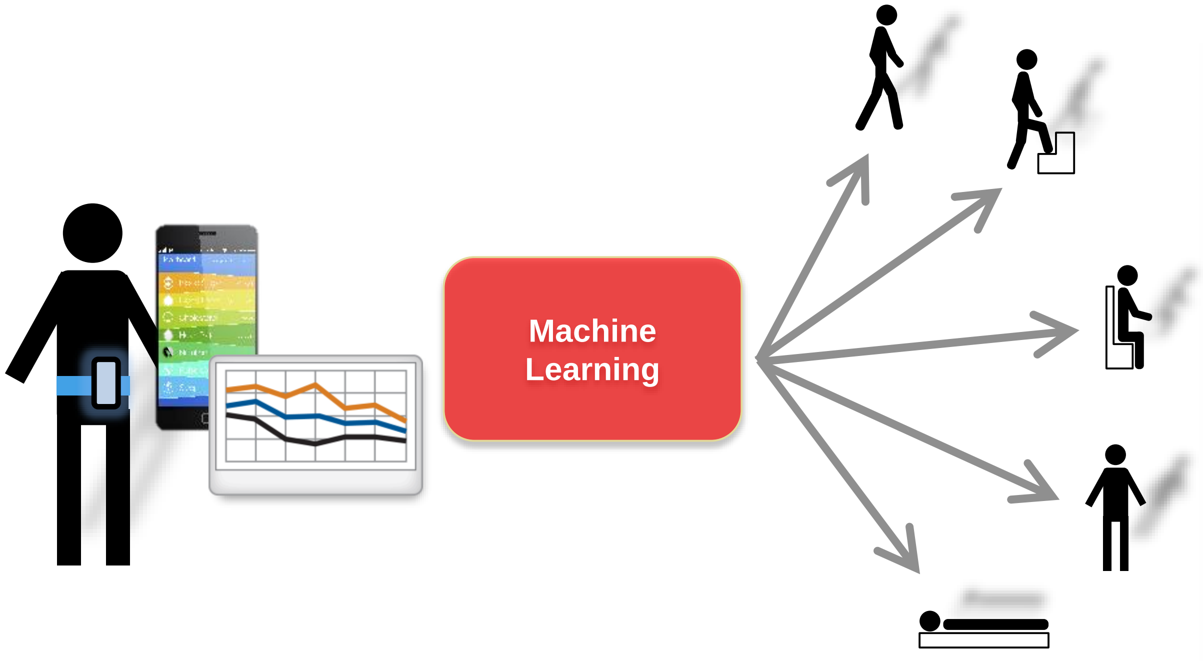
Machine Learning Approach

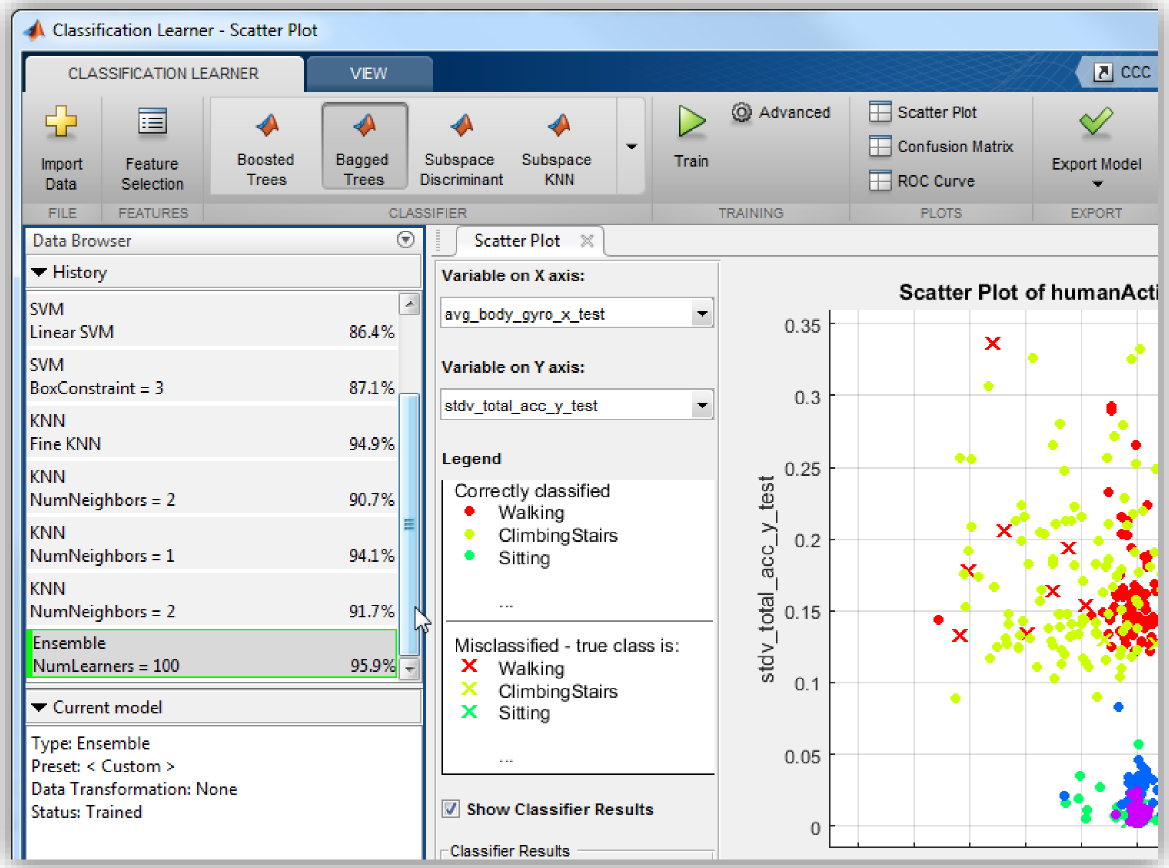


$$model: \text{Inputs} \rightarrow \text{Outputs}$$

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

Example: Human Activity Learning Using Mobile Phone Data





Data:

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

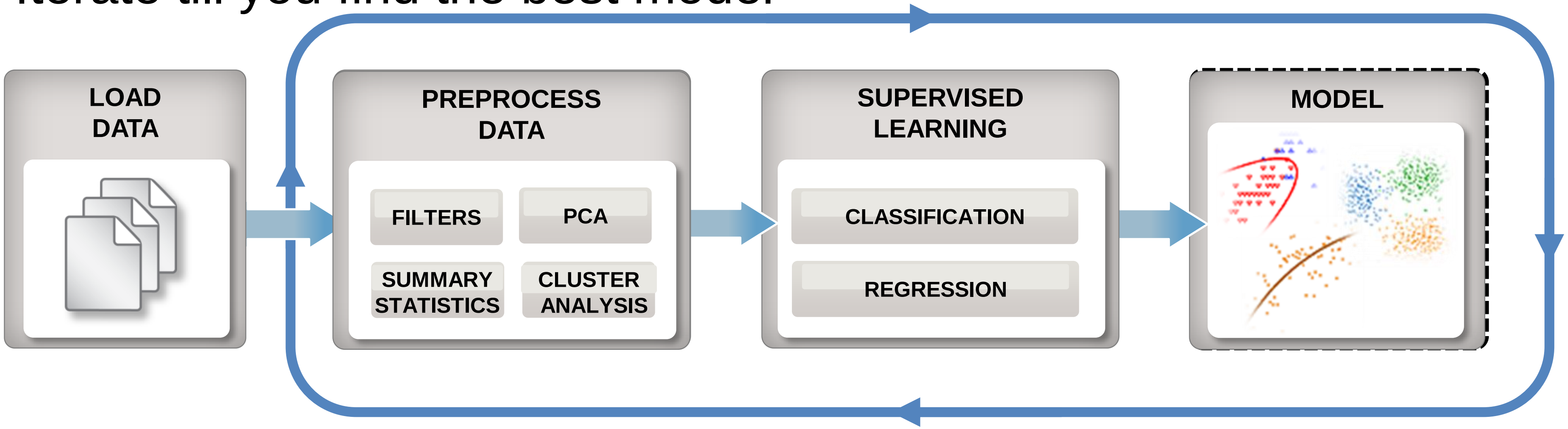
Challenges in Machine Learning

Hard to get started

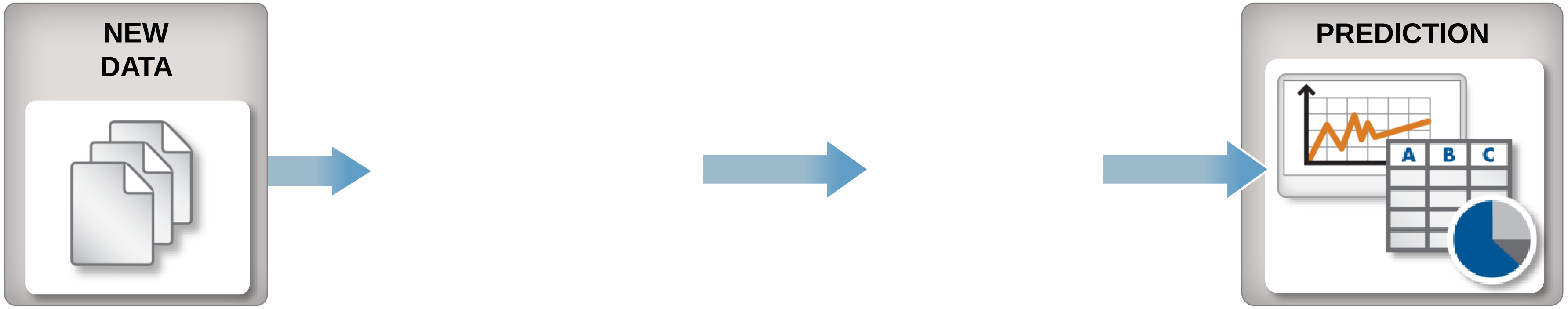
Steps	Challenge
Access, explore and analyze data	**Data diversity** Numeric, Images, Signals, Text – not always tabular

Machine Learning Workflow

Train: Iterate till you find the best model



Predict: Integrate trained models into applications



Agenda

- Machine Learning
  - What is Machine Learning and why do we need it?
  - Common challenges in Machine Learning
- Example 1: Human activity learning using mobile phone data
  - Learning from sensor data
- Example 2: Real-time car identification using images
  - Learning from images
- Summary & Key Takeaways

Example 1: Human Activity Learning Using Mobile Phone Data

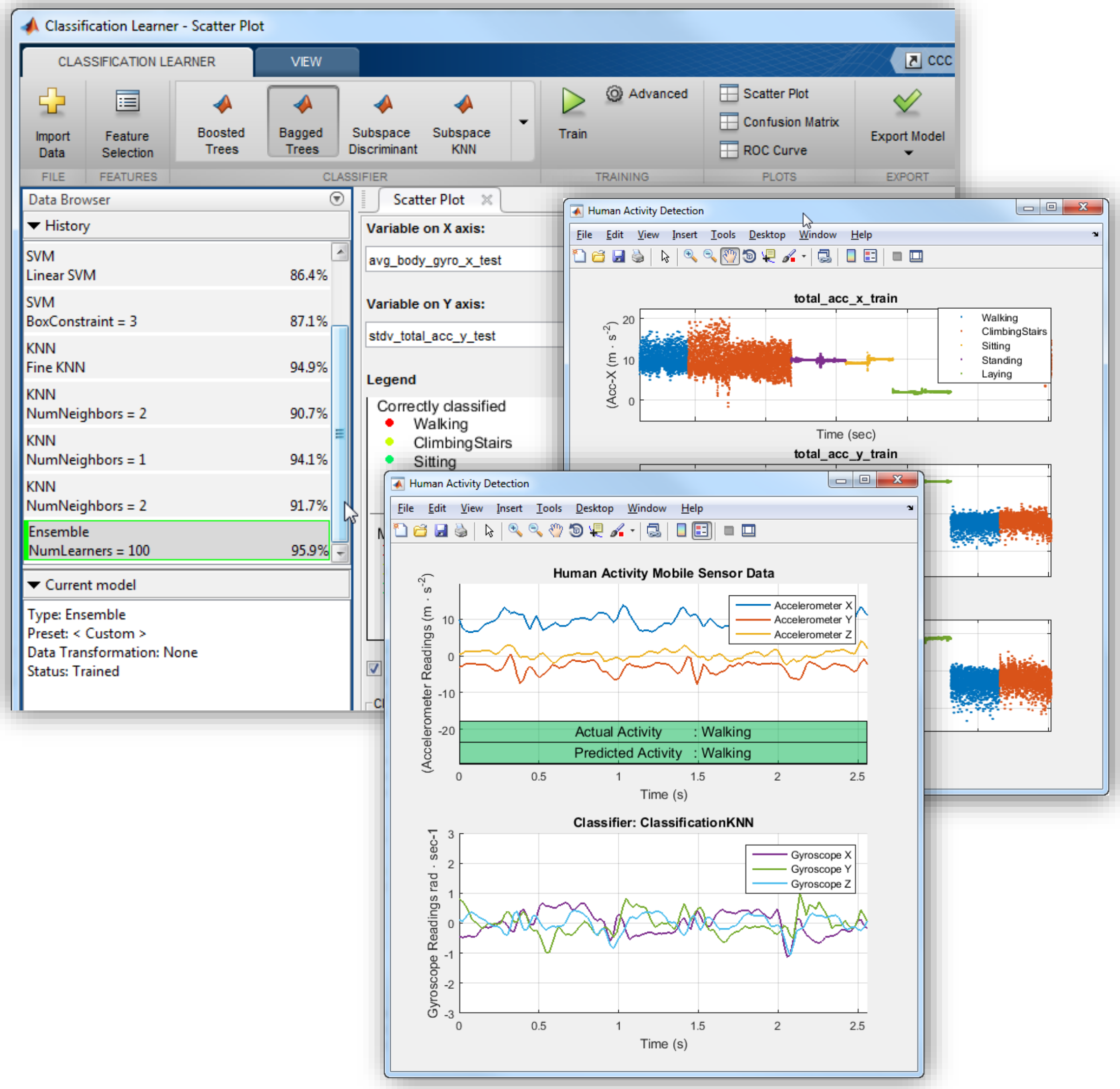
Objective: Train a classifier to classify human activity from sensor data

Data:

Predictors	3-axial Accelerometer and Gyroscope data 
Response	Activity: 

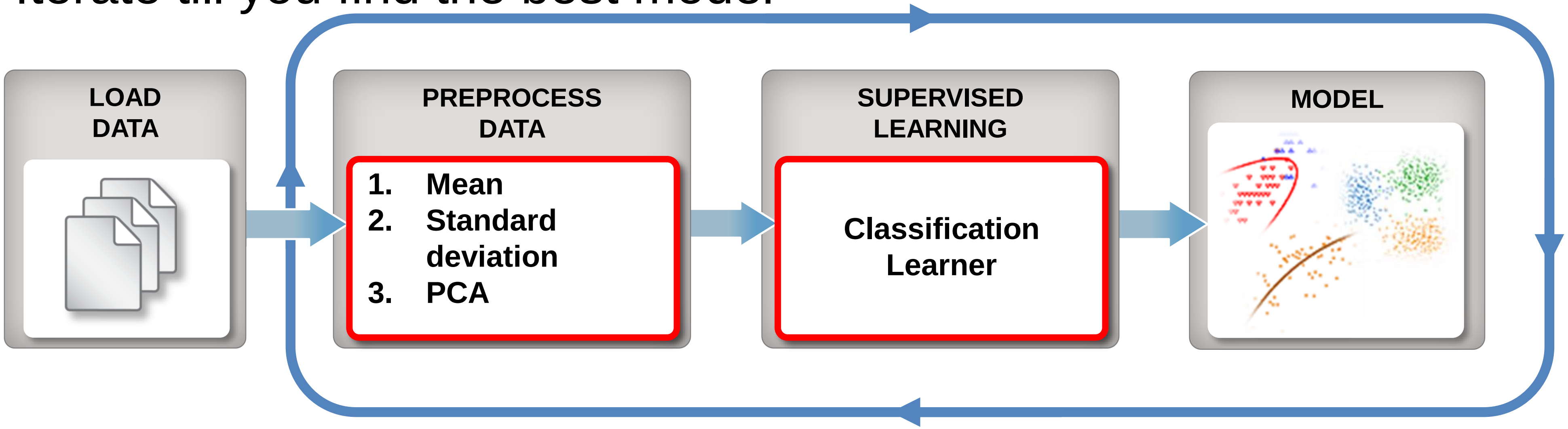
Approach:

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

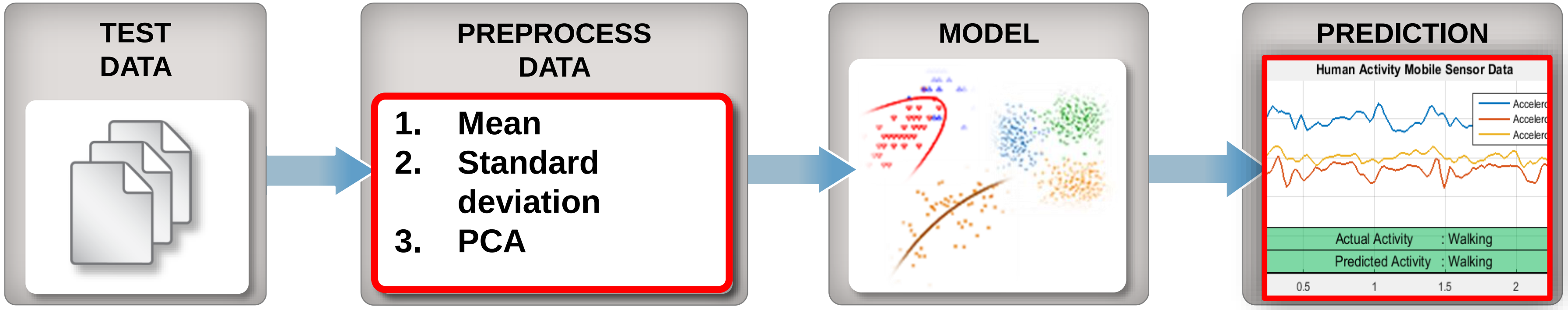


Machine Learning Workflow for Example 1

Train: Iterate till you find the best model



Predict: Integrate trained models into applications



Agenda

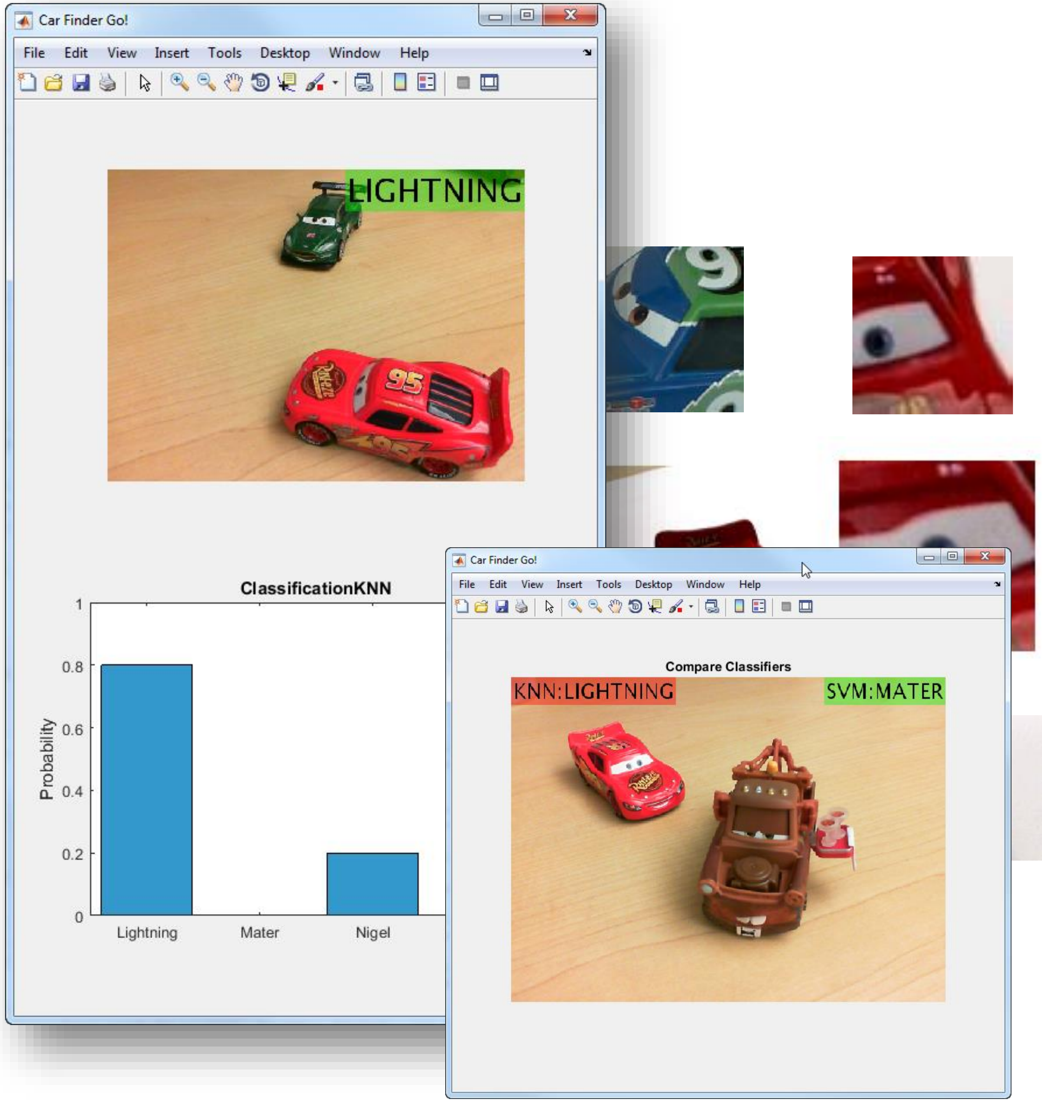
- Machine Learning
  - What is Machine Learning and why do we need it?
  - Common challenges in Machine Learning
- Example 1: Human activity learning using mobile phone data
  - Learning from sensor data
- Example 2: Real-time car identification using images
  - Learning from images
- Summary & Key Takeaways

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

LOAD DATA

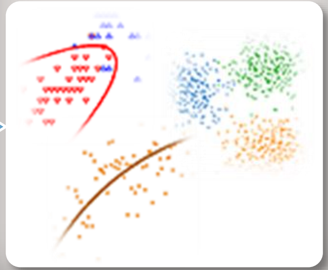
PREPROCESS DATA

1. Build Bag-of-features
2. Encode images as new features

SUPERVISED LEARNING

Classification Learner

MODEL



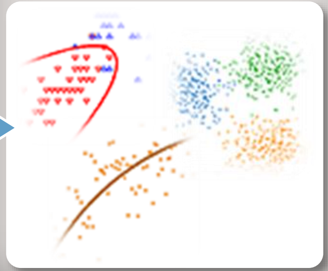
Predict: Integrate trained models into applications

WEBCAM

PREPROCESS DATA

Encode images as new features

MODEL



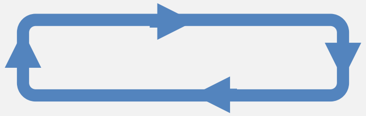
PREDICTION

Agenda

- Machine Learning
  - What is Machine Learning and why do we need it?
  - Common challenges in Machine Learning
- Example 1: Human activity learning using mobile phone data
  - Learning from sensor data
- Example 2: Real-time car identification using images
  - Learning from images
- Summary & Key Takeaways

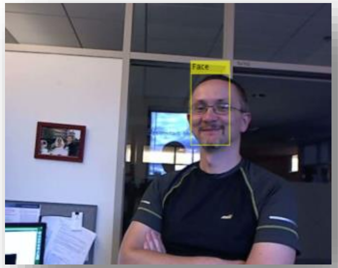
Challenges in Machine Learning

MATLAB Strengths for Machine Learning

Steps	Challenge
Accessing, exploring and analyzing data	**Data diversity**
Preprocess data	**Lack of domain tools**
Train models	**Time consuming**
Assess model performance	**Avoid pitfalls** Over Fitting, Speed-Accuracy-Complexity
Iterate	

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

Agenda – Day 1

Day 1

09:00 am - 09:30 am	Registration
09:30 am - 09:45 am	Welcome Address
09:45 am -11:00 am	MATLAB and Simulink in Engineering Education MATLAB Basics for the Budding Engineer •Experimentation and Modeling in MATLAB •Design and Implementation •Project-Based Learning (Arduino, RaspberryPi) •Machine Learning & Data Analytics
11:00 am - 11:30 am	Tea Break
11:30 am - 12:30 pm	•Accessing, exploring, analyzing, and visualizing data in MATLAB •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
12:30 pm - 2:30 pm	Lunch Break
02:30 pm - 04:30 pm	•Electrical engineering concepts Using MATLAB and Simulink •System Identification & Neural Network Based System Modeling Techniques •Electrical engineering using Simscape (Physical Modeling) •Electrical engineering using SimPowersystems •Control system design and analysis •What is IoT? • Market Drivers and Challenges • Introduction to ThingSpeak • Examples • Other IoT examples using MW tools • MATLAB and Simulink Capabilities for IoT
04:30 pm - 05:00 pm	Tea Break

Agenda – Day 2

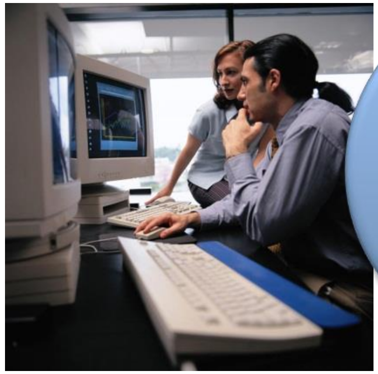
Day 2

10:00 am -11:00 pm	•Mechanical engineering and Control System Concepts Using MATLAB and Simulink. Mechanical engineering concepts using Simscape (Physical Modeling) •Multi-Body Dynamics Simulation using SimMechanics
11:00 am - 11:30 am	Tea Break
11:30 am - 01:00 pm	•Import CAD Models using GetMechanics App •Implement Control on Low cost hardware - Arduino •Demo of Magnetic Levitation System
1:00 pm - 2:00 pm	Lunch Break

What wakes you up in the morning?

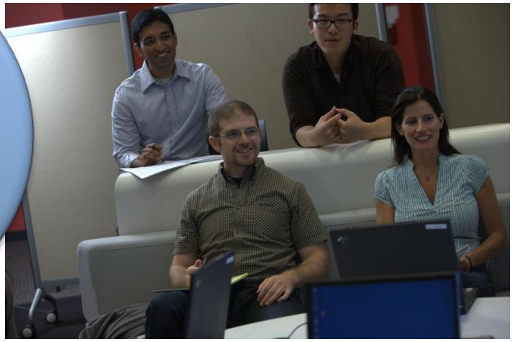
Professors

- Attract, engage, and retain students?
- Equip them to succeed in industry?
- Educate students with theory, modelling, hands-on practice, and a systems perspective?



Researchers

Students



- Able to analyse all the data?
- Discovering at the right pace?
- Spending your time effectively?
- Accessing the right tools to collaborate in a multi-disciplinary environment
- Leveraging the computer power?

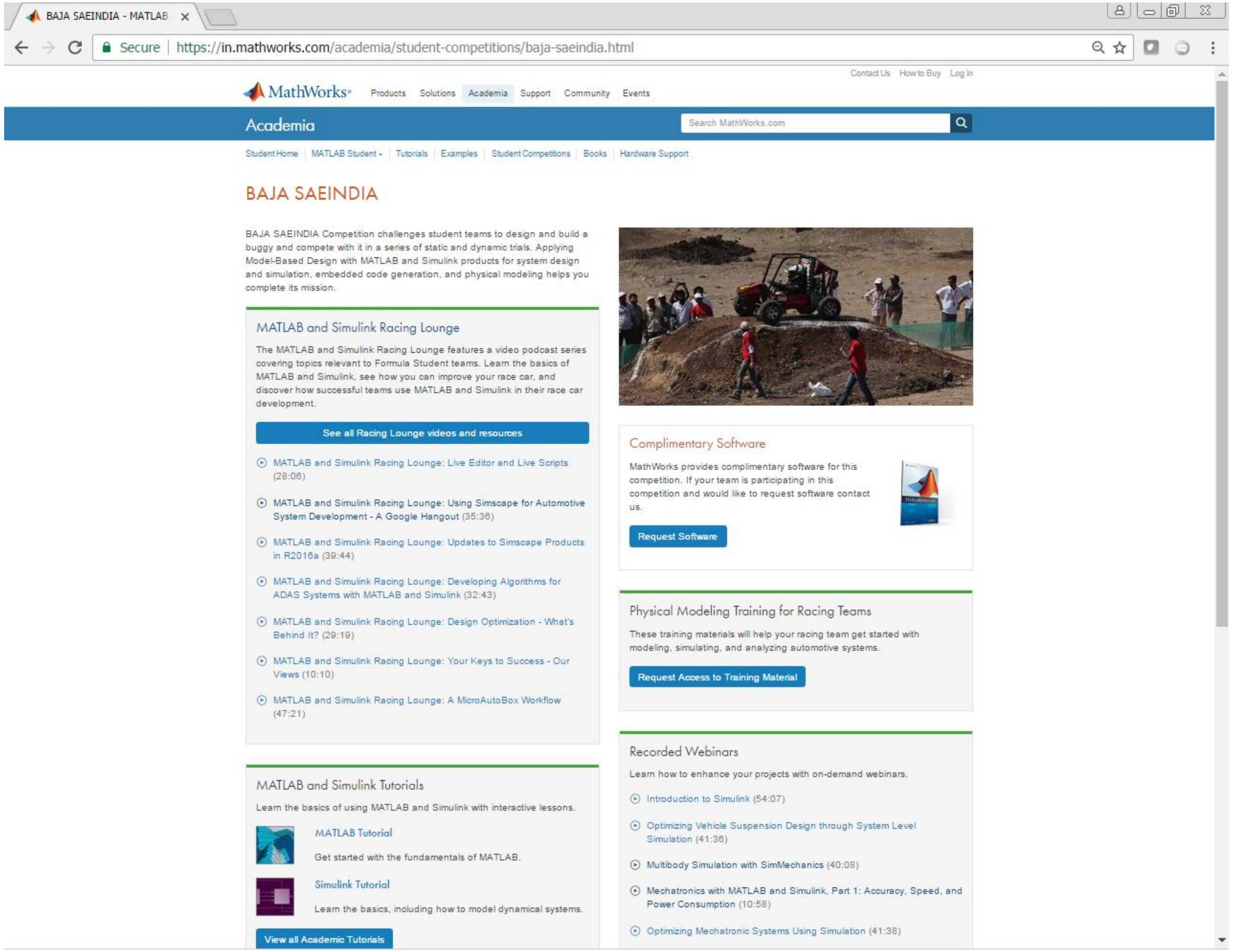
- Going to find a job?
- Able to bring innovation?
- Be competitive in a global economy?

Student Algorithms in Action

Student Competitions- IIT Bombay Racing team

- The only Indian car ever to finish endurance at Formula Student UK.
- EVo 3.0 was among only 9 Electric Cars (out of 32) to finish the endurance run at FS UK'14
- A professional outlook towards the project, healthy relationship with the industry and a good testing time for the car, helped us rise to a respectable performance at Formula Student this season

BAJA SAE India



Vibrational analysis of dynamic mechanical system using Simulink and Simscape

How do we model 2 DOF mechanical system?

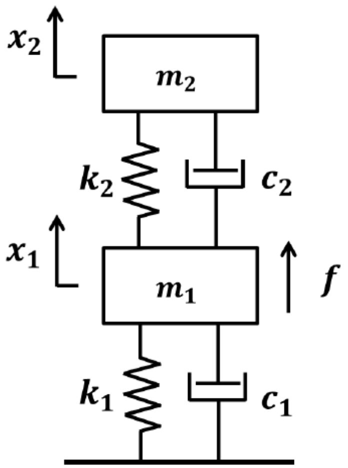
DOF: Degrees-Of-Freedom

- Equation of motion

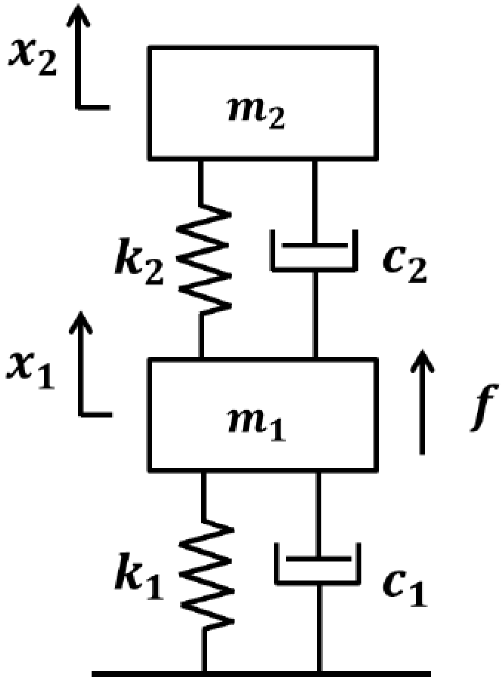
$$m_1\ddot{x}_1 + c_1\dot{x}_1 + k_1x_1 + c_2(\dot{x}_1 - \dot{x}_2) + k_2(x_1 - x_2) = f$$

$$m_2\ddot{x}_2 + c_2(\dot{x}_2 - \dot{x}_1) + k_2(x_2 - x_1) = 0$$

m_1, m_2	Mass [kg]
c_1, c_2	Viscous damping coefficient [Ns/m]
k_1, k_2	Spring stiffness [N/m]
x_1, x_2	Position [m]
f	External force [N]



2 DOF system

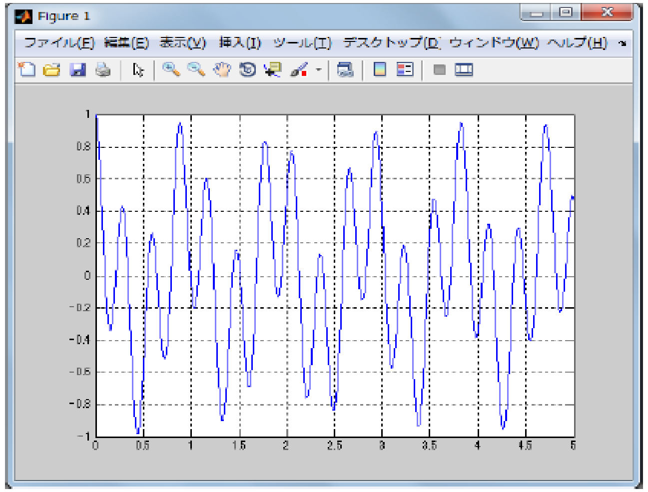


Vibrational analysis of dynamic mechanical system using Simulink and Simscape

MATLAB Model

- Define ordinary differential equations using MATLAB and Toolboxes
- Time- and frequency- domain simulation
  - ODE solver in MATLAB
  - Control System Toolbox

```
%% Create System Matrices

M = [m1 0 ; 0 m2];
C = [c1+c2 -c2 ;-c2 c2];
K = [k1+k2 -k2 : -k2 k2];

Ap = [zeros(2) eye(2) ; -M¥K -M¥C]
Bp = [zeros(2,1); 1 ; 0];
Cp = [1 0 0 0]; % Measured x1 only
Dp = 0;
```

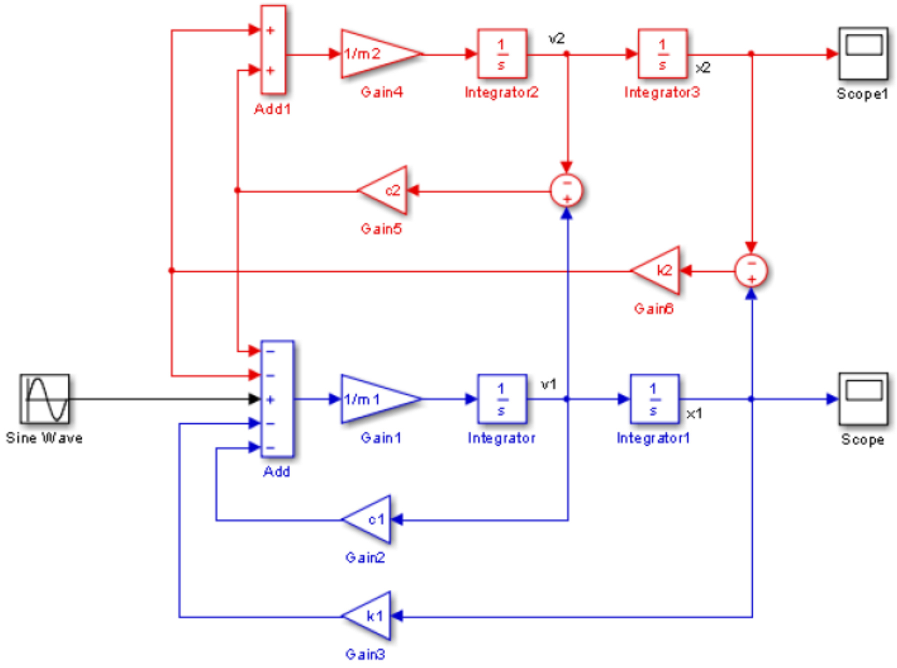


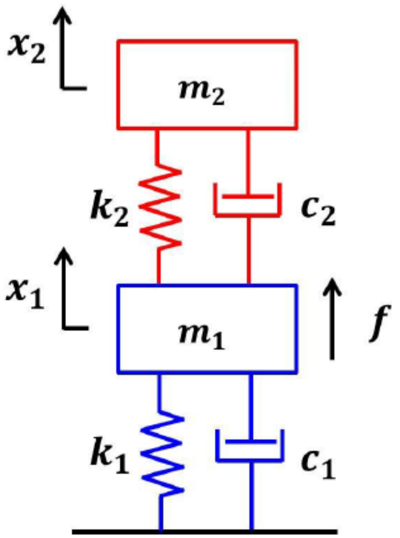

```
%% Initial Time Response Simulation using ODE Solver

tspan = [0 5]; % Interval of integration
X0 = [1 ;0.1; 0 ;0]; % Initial condition
options = odeset('MaxStep',1e-3);
[T,X] = ode45(@diff2dof,tspan,X0,options,Ap);
plot(T,X(:,1))
```

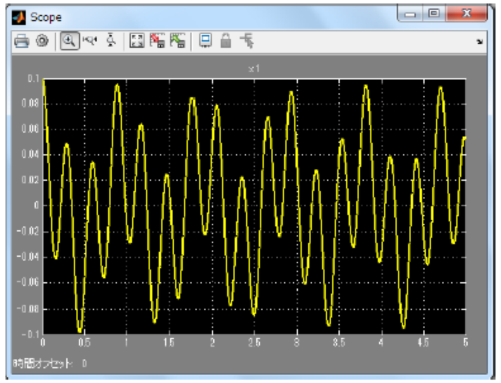
Vibrational analysis of dynamic mechanical system using Simulink and Simscape

Simulink Model

- Graphical modeling in block-diagram environment







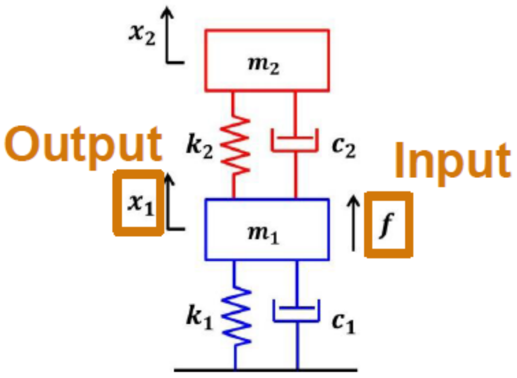
$$m_1 d^2x_1/dt^2 + c_1\, dx_1/dt + k_1 x_1 + c_2(dx_1/dt-dx_2/dt) + k_2(x_1-x_2) = f$$

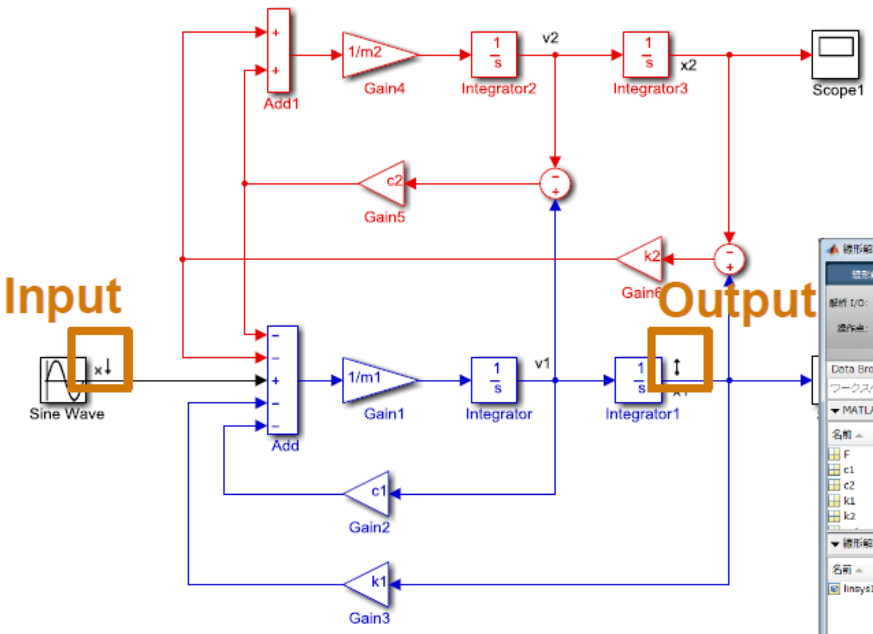
$$m_2 d^2x_2/dt^2 + c_2(dx_2/dt-dx_1/dt) + k_2(x_2-x_1) = 0$$

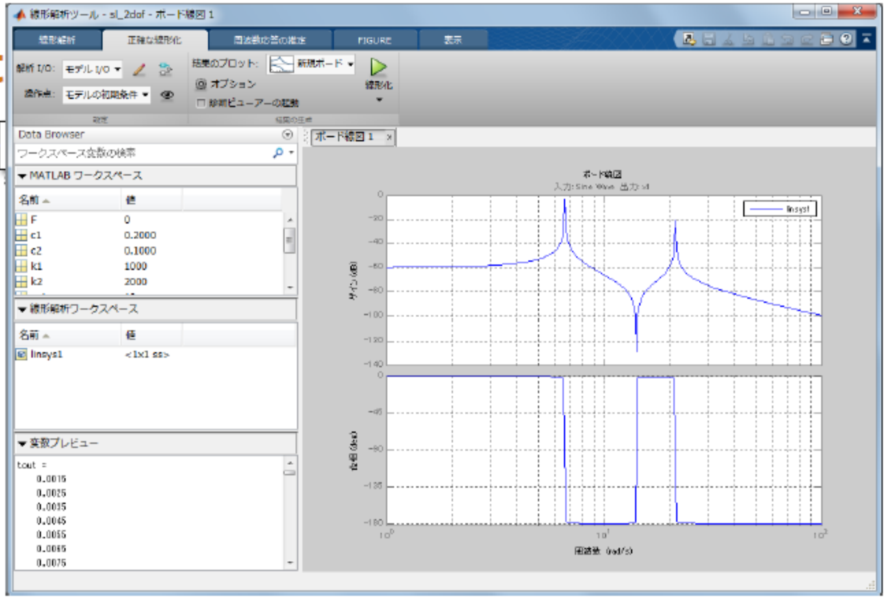
Vibrational analysis of dynamic mechanical system using Simulink and Simscape

Frequency-Domain Analysis in Simulink

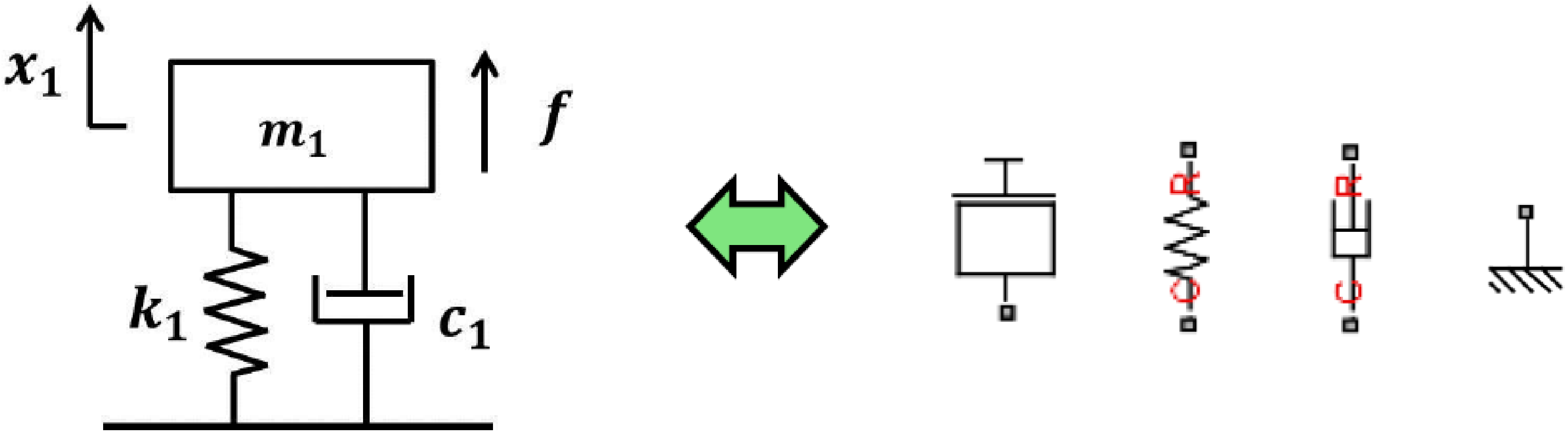
- Bode plot for any input-output specified in Simulink model







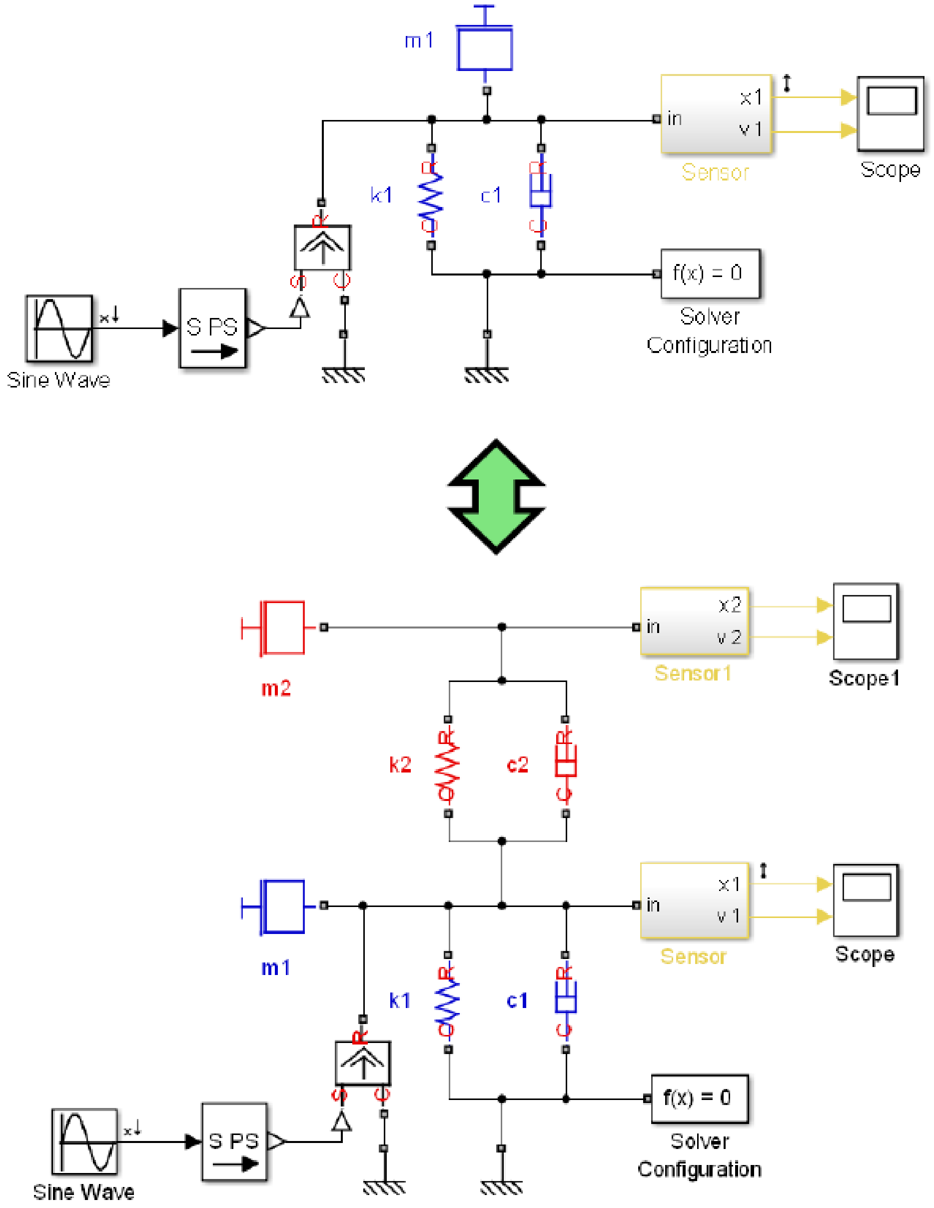
There Has to Be a More Efficient Way of Modeling?



Assemble physical system
by connecting physical components

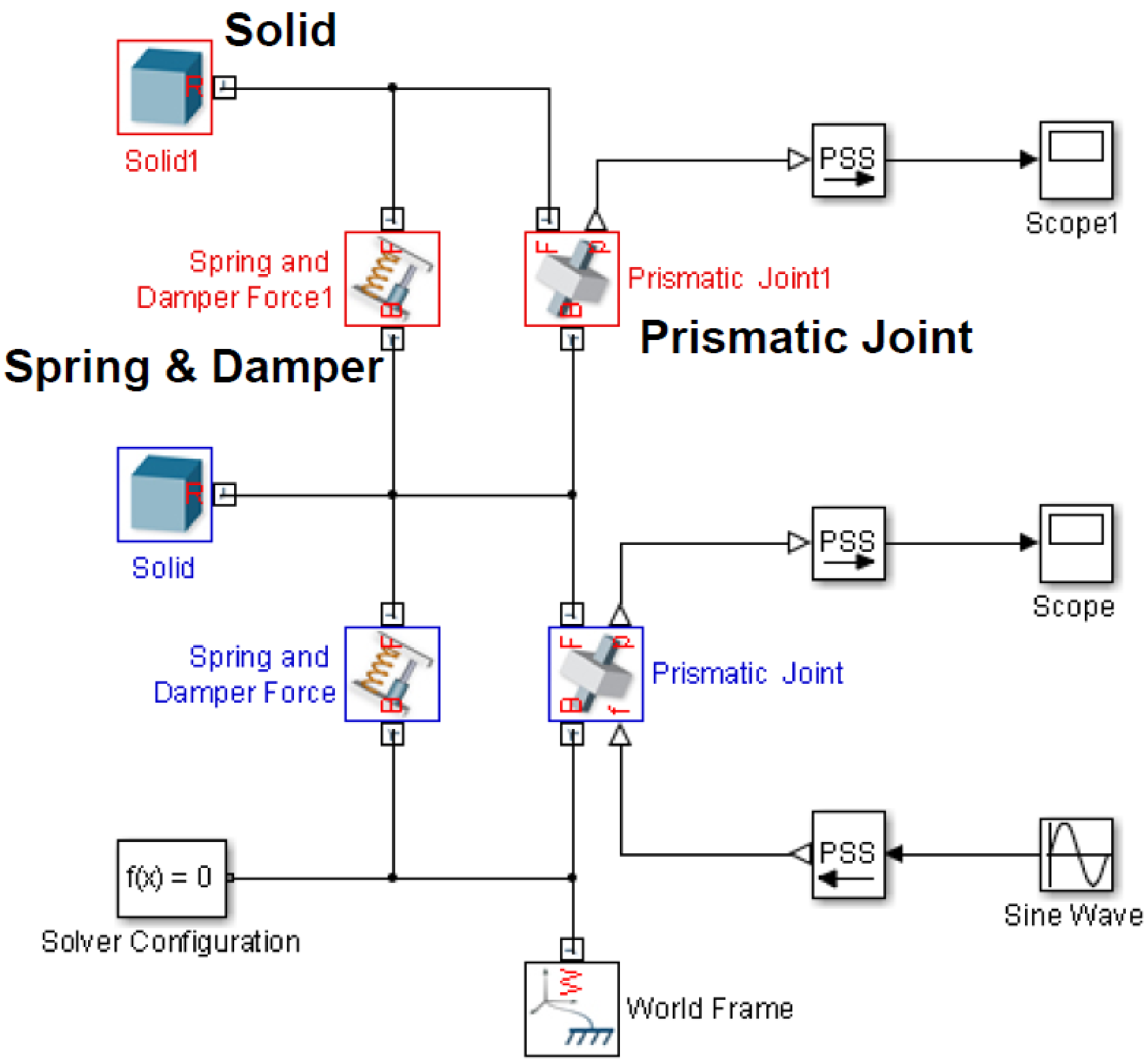
Physical Network Approach

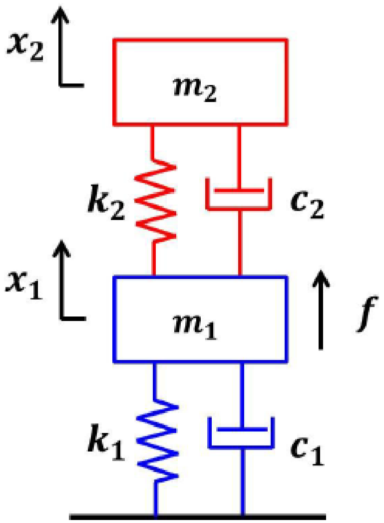
- Easier to read
- Easier to reuse
- Leverage MATLAB and Simulink
  - System-level simulation
  - System optimization
  - Control design

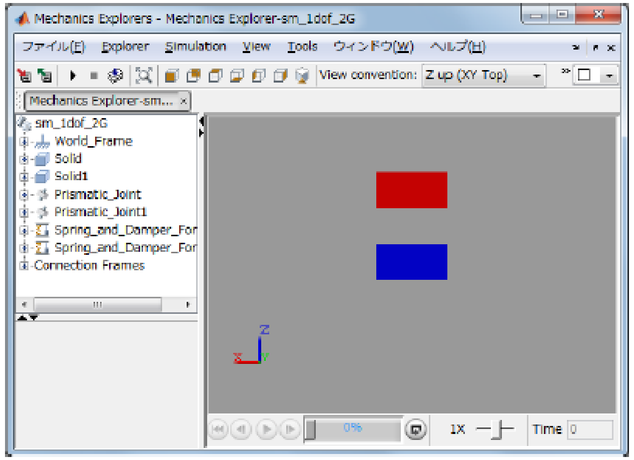


SimMechanics

2 DOF system (3D)



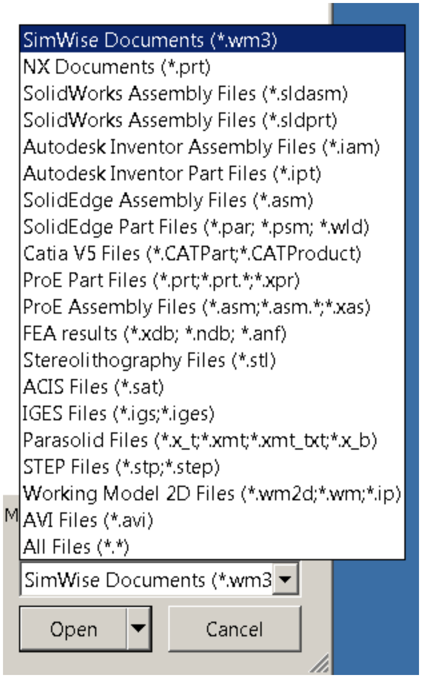


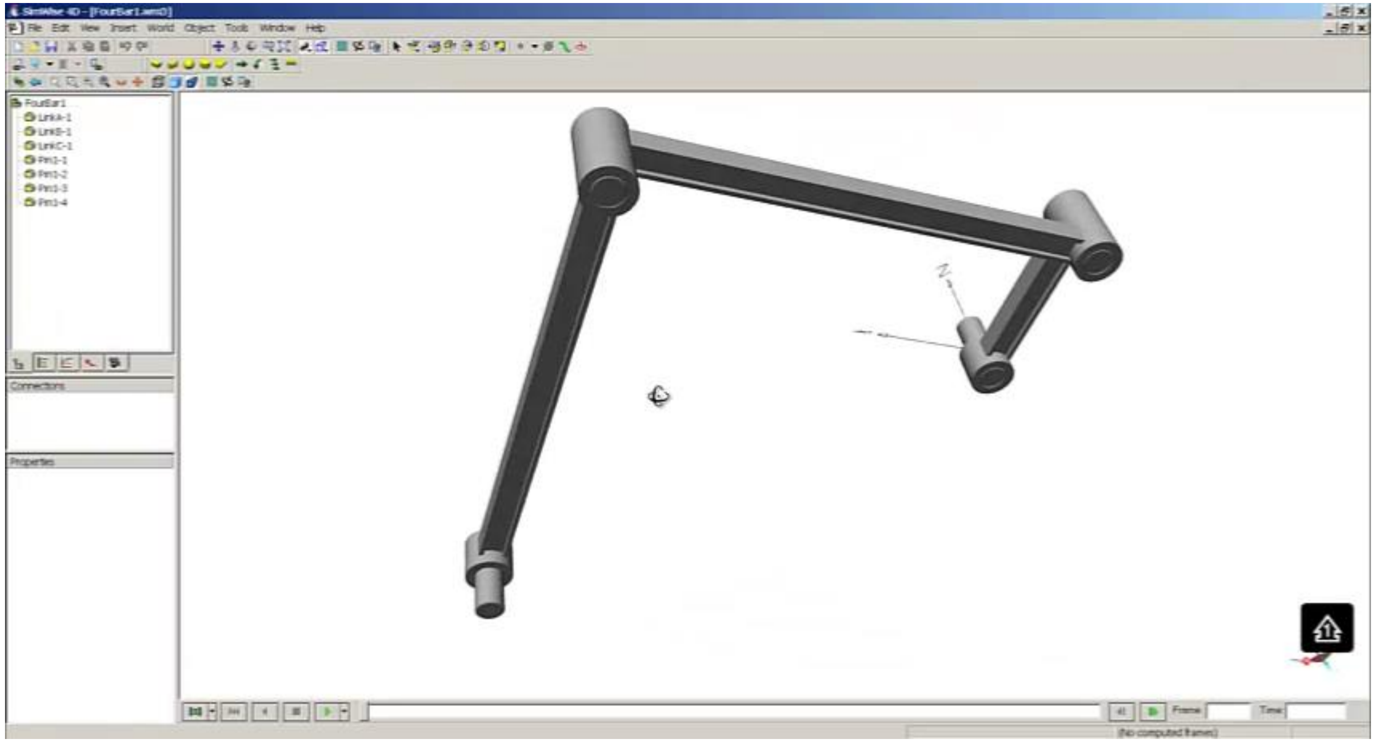


Content

- Importing CAD models
- Automatically Create SimMechanics Models using GetMechanics App
- Performing Co-Simulation with SimWise 4D
- Simulating Controls, FEA, Dynamics, Thermal, Sound and Vibration in one go.

Importing CAD models

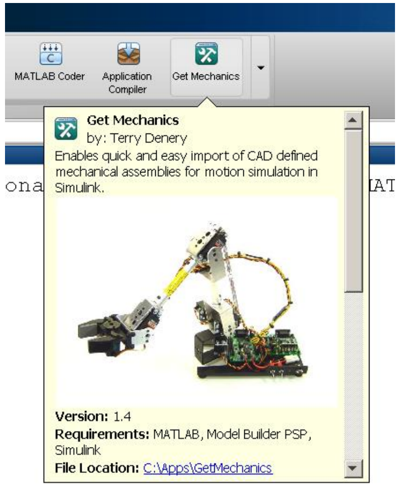


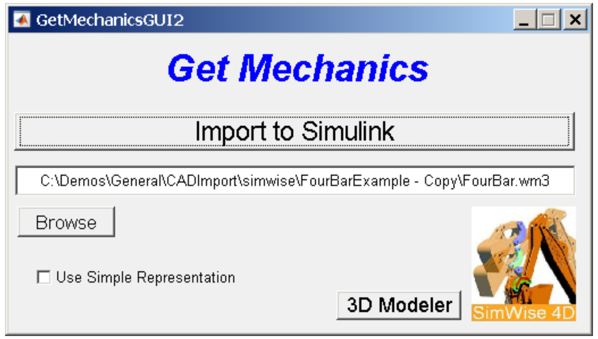


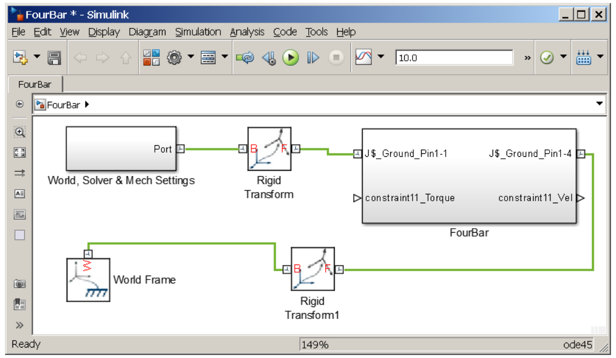
Open the CAD model in Simwise 4D

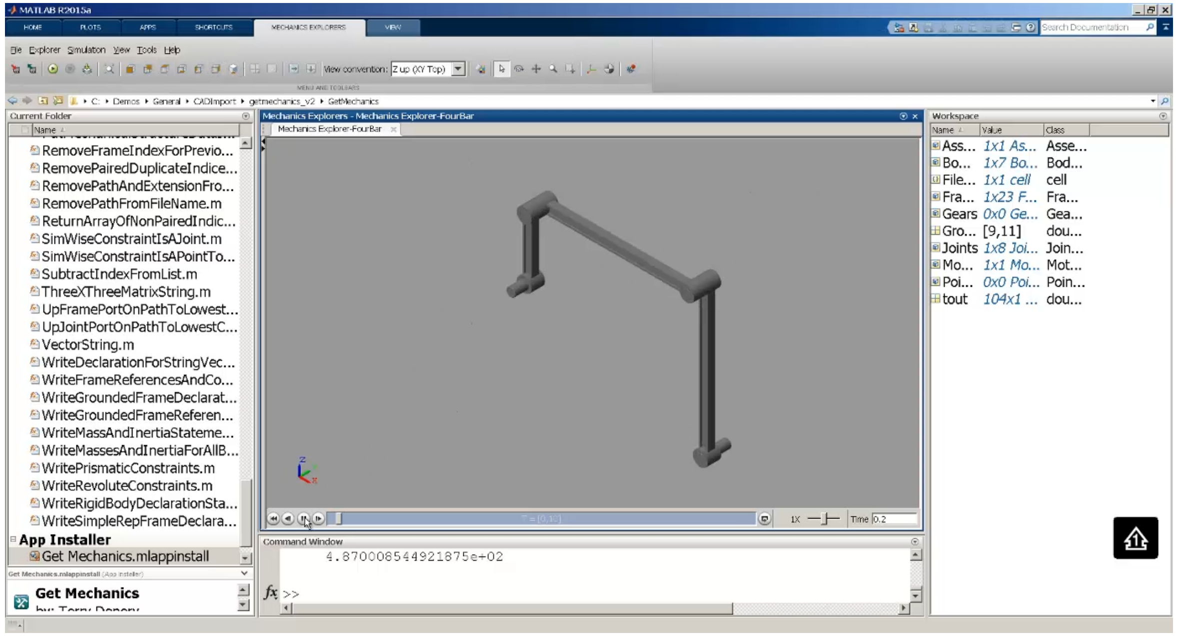
SimWise converts the CAD model into
SimMechanics convertible format (*.wm3)

Automatically Create SimMechanics Models using GetMechanics App





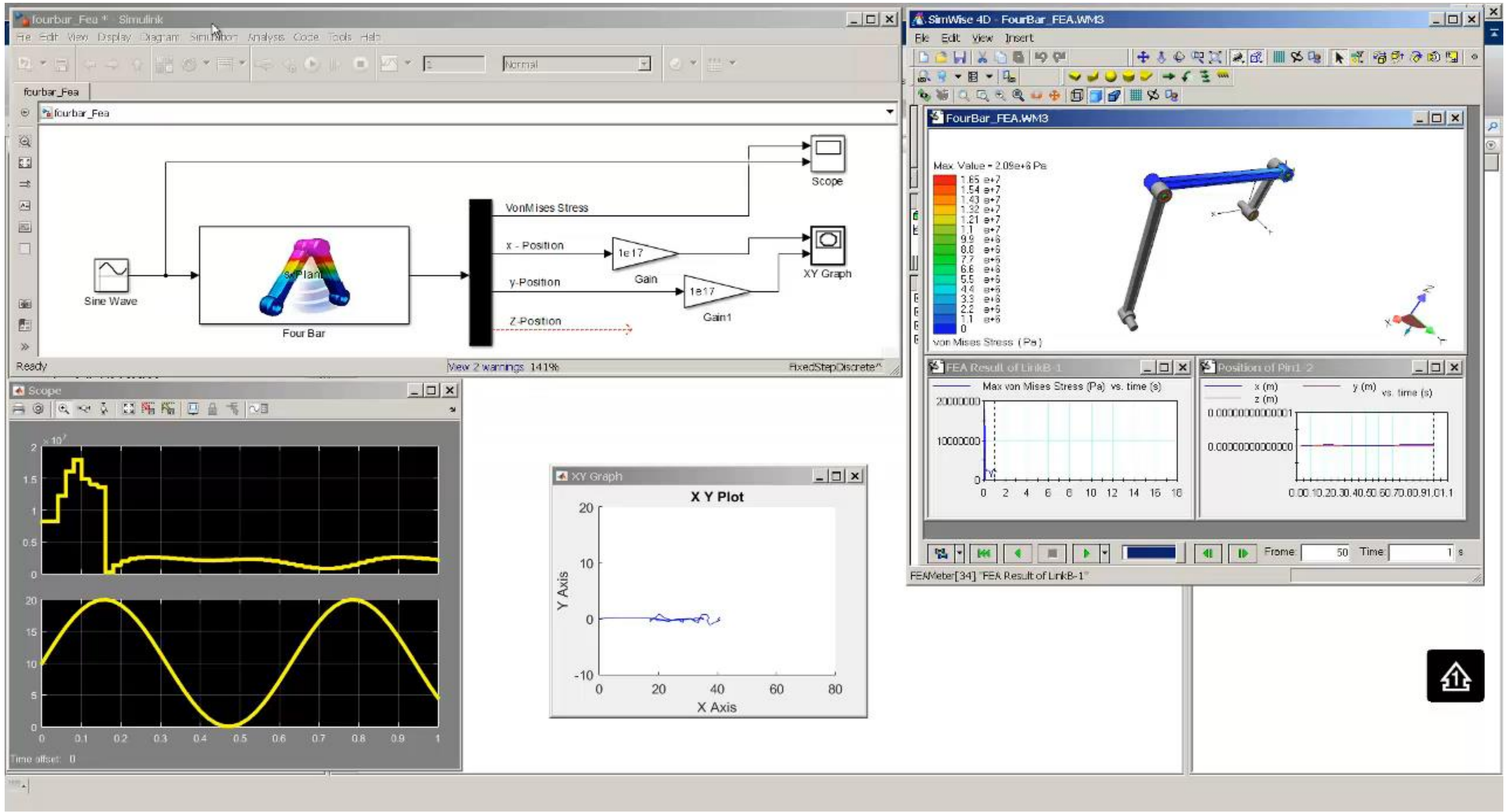




GetMechanics App can import SimWise *.wm3 file

To get GetMechanics App Contact MathWorks

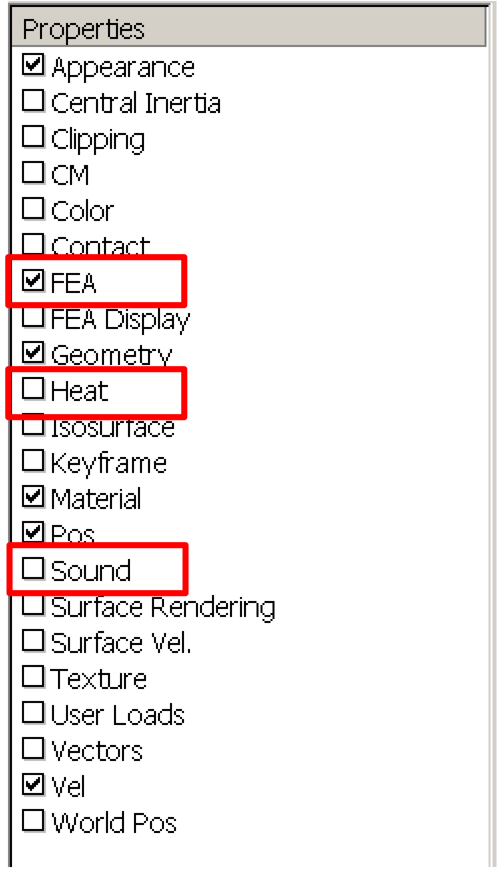
Performing Co-Simulation with SimWise 4D

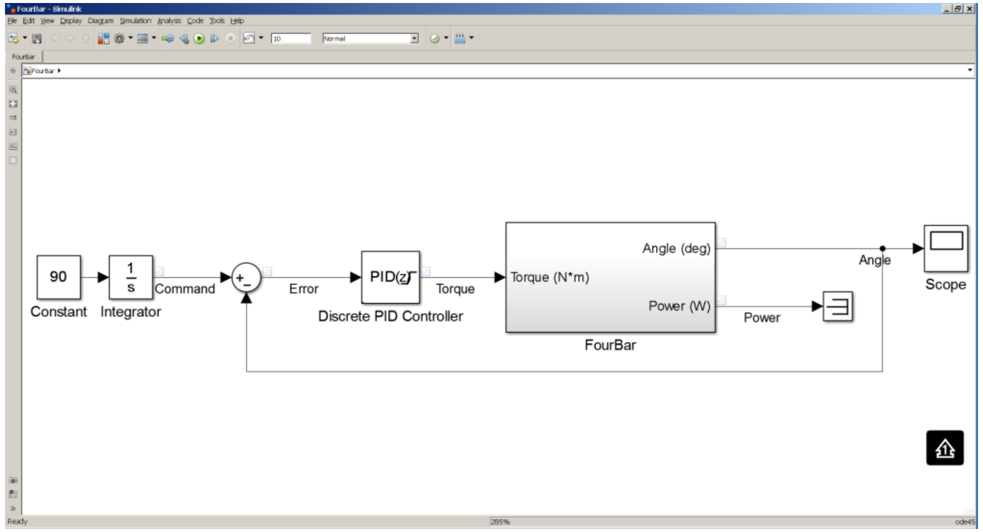


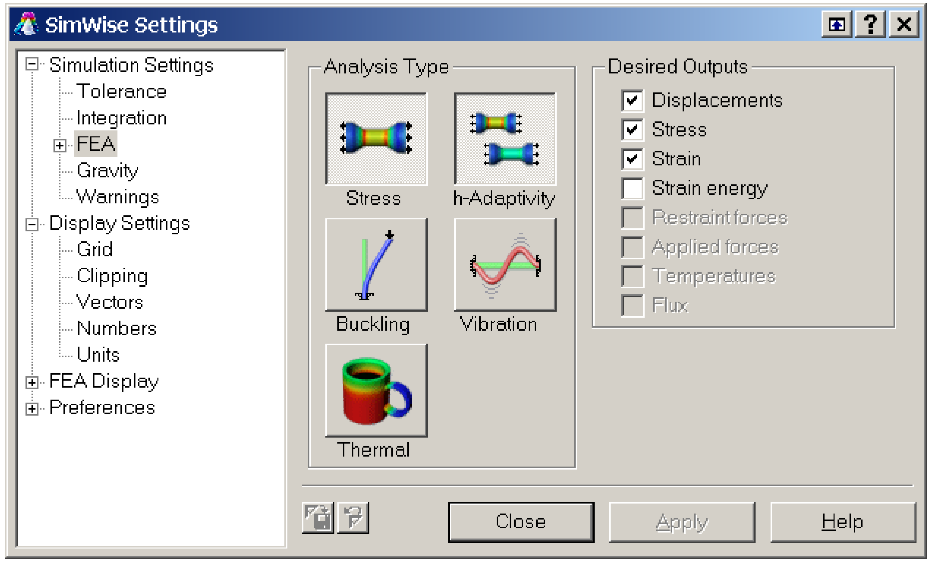
Use MATLAB for Controls Modeling and Leverage MATLAB capabilities.

Perform Plant Simulation in SimWise 4D for Multibody Dynamics, FEA, Heat, Vibration, Buckling, Durablity and Realiability.

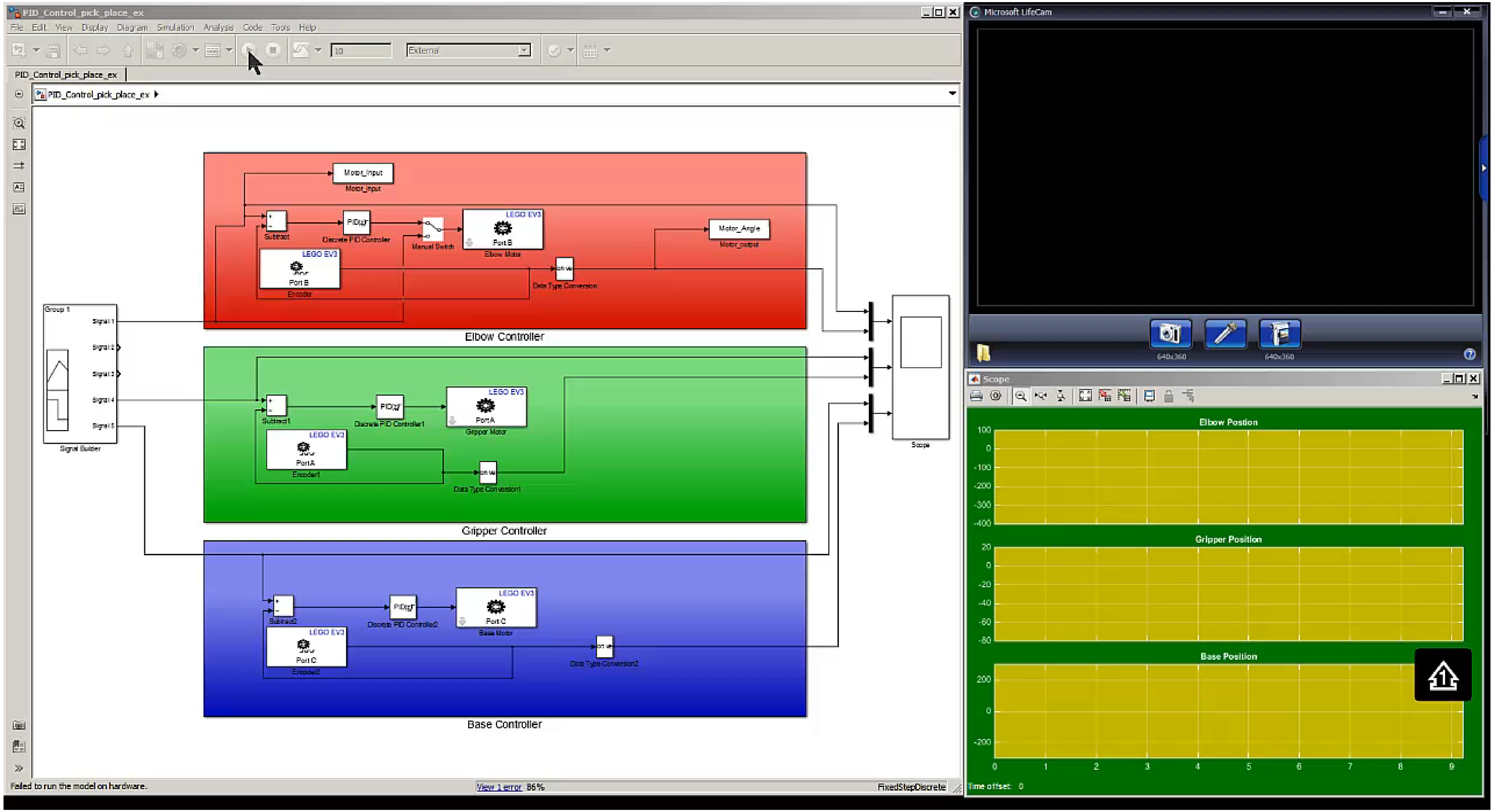
Simulating Controls, FEA, Dynamics, Thermal, Sound and Vibration in one go.

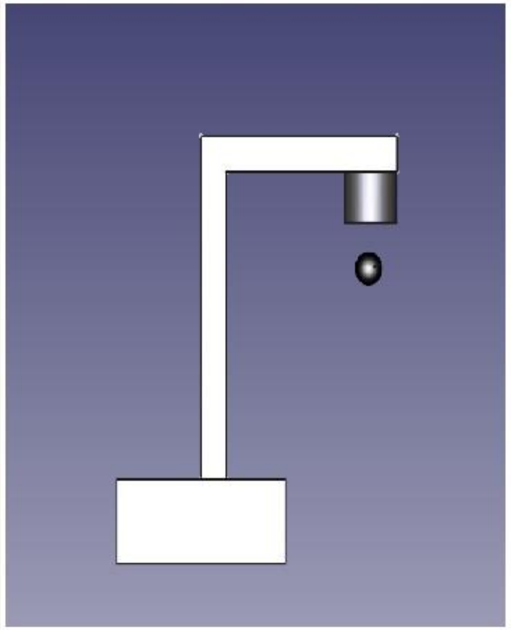


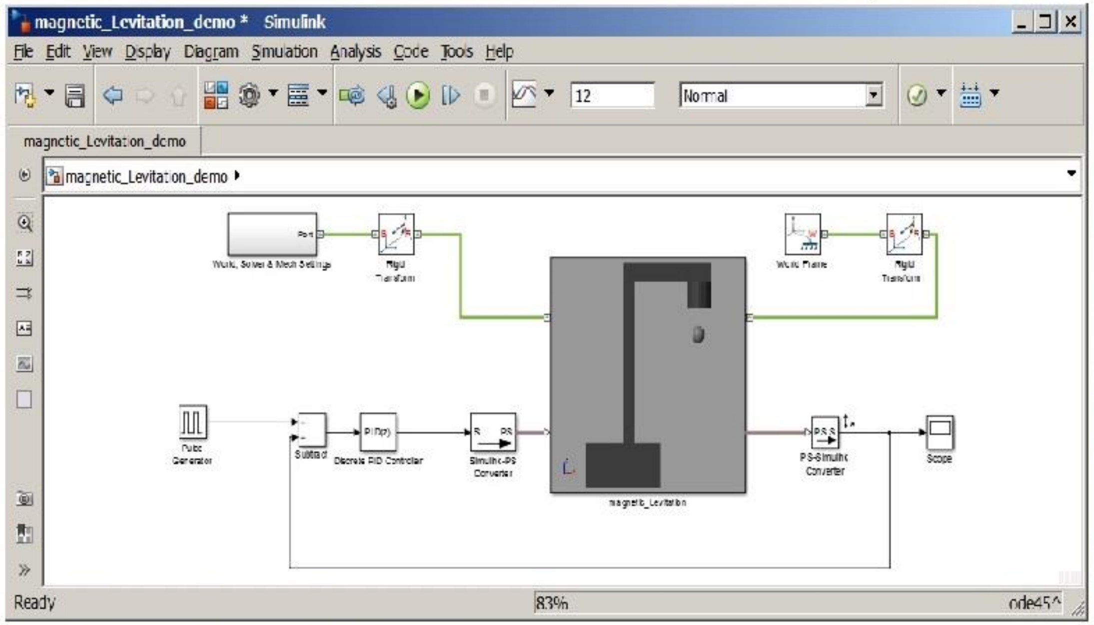




Performing multi-body dynamic system using SimMechanics







CAD File (import) **Simulink Model** (code generatoin) **Prototype**

Thank You

My Contact

dsingh@mathworks.com

+91 9920288785