

Enabling Project-Based Learning with MATLAB, Simulink, and Target Hardware

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Why Project-Based Learning?

“When they went to school, the first thing they [children] had to learn was to **stop learning** and to **begin being taught.**”

– Dr. Seymour Papert
Massachusetts Institute of Technology

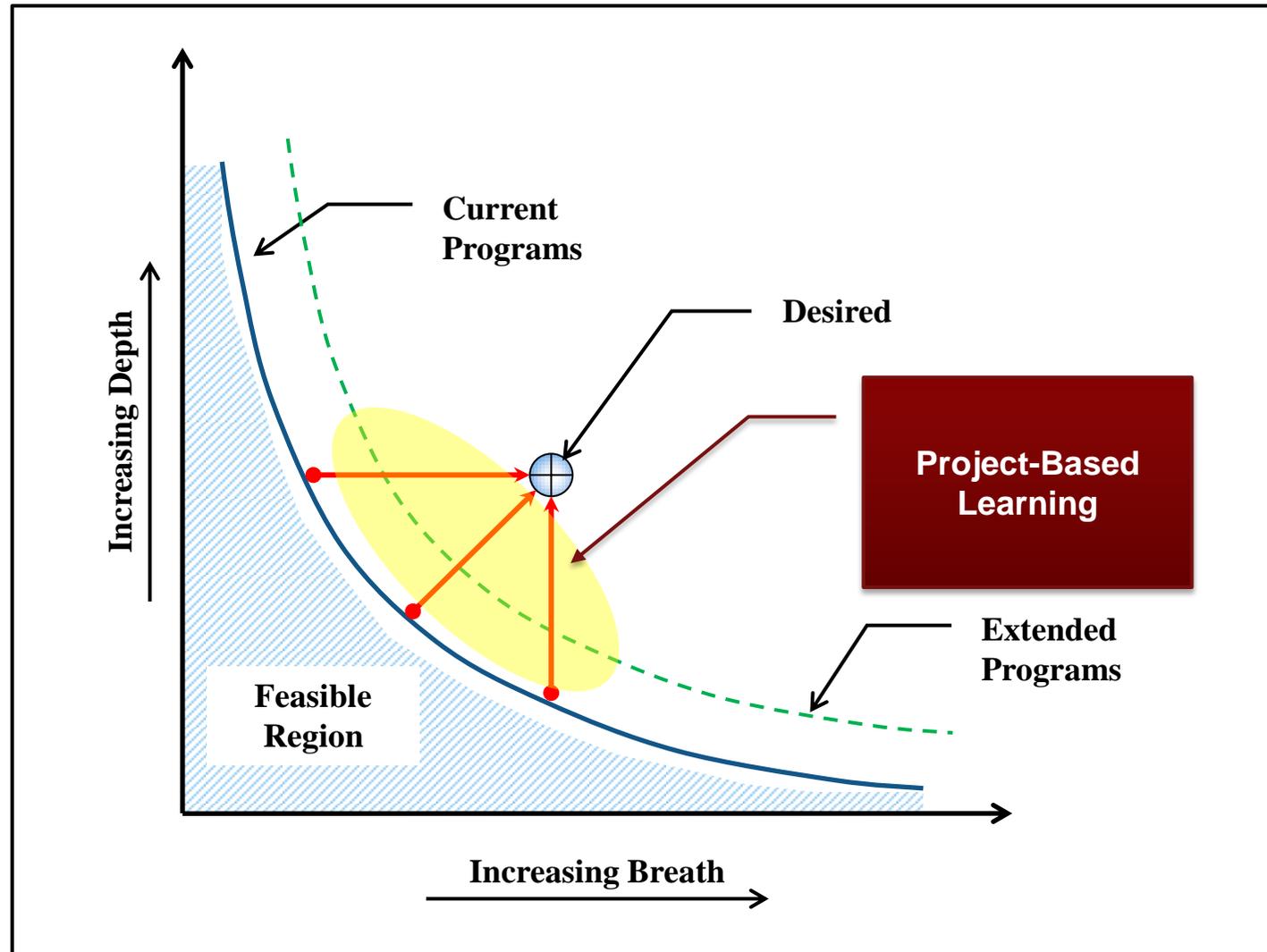
Keynote: National School Boards Association Technology and Learning Conference 1994

IEEE Survey: Industry Expectations for Entry-level Control Engineers and New Graduates

| | Industry View: Essential, Important, or Useful | Faculty View: Key part of the curriculum |
|--|--|---|
| Linear Models | 96.4% | 95.6% |
| Control-Oriented Models for System Design | 98.2% | 67.0% |
| Simulation Models for System Verification or Product Development | 94.5% | 48.5% |
| Nonlinear Models | 90.9% | 42.3% |
| Finite State Machine Models | 82.9% | 33.0% |
| Real-Time Models for Hardware-in-the-Loop Verification or Training | 94.4% | 25.8% |

Nov. 2009 Controls Curriculum Survey:
 An IEEE Control Systems Society Outreach Task Force Report
http://ieeecss.org/sites/ieeecss.org/files/documents/CSSSurvey07AugustData_v3.pdf

Challenge: Trade-offs in Engineering Curricula



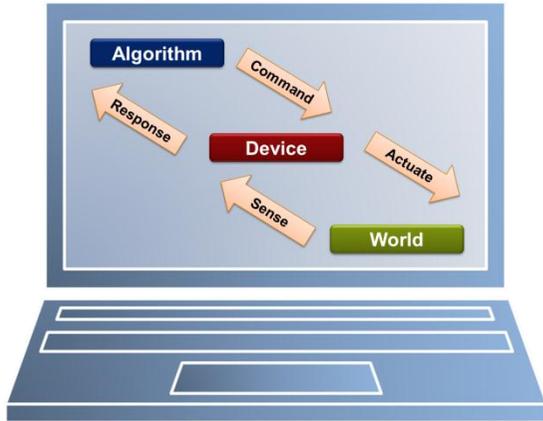
Project-Based Learning

Project-based learning is a comprehensive approach to classroom teaching and learning that is designed to **engage** students in **investigation** of **authentic problems**.

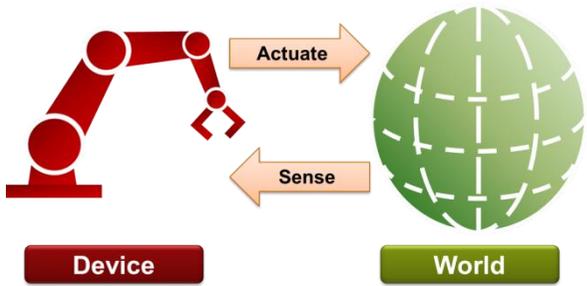
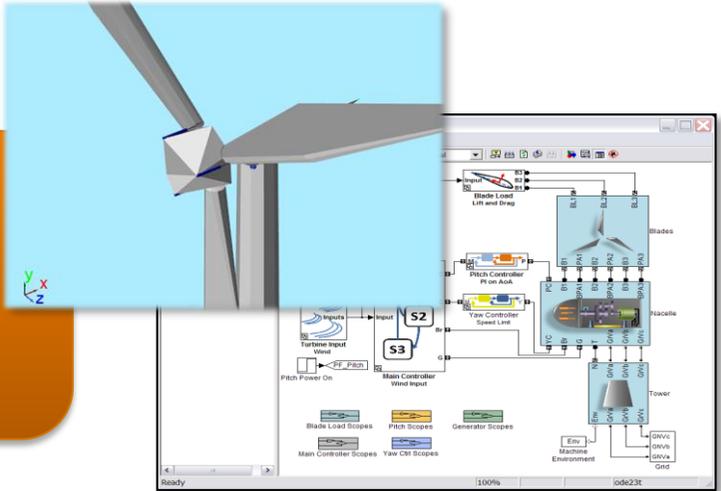


Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning, Educational Psychologist [Volume 26, Issue 3-4](#), 1991

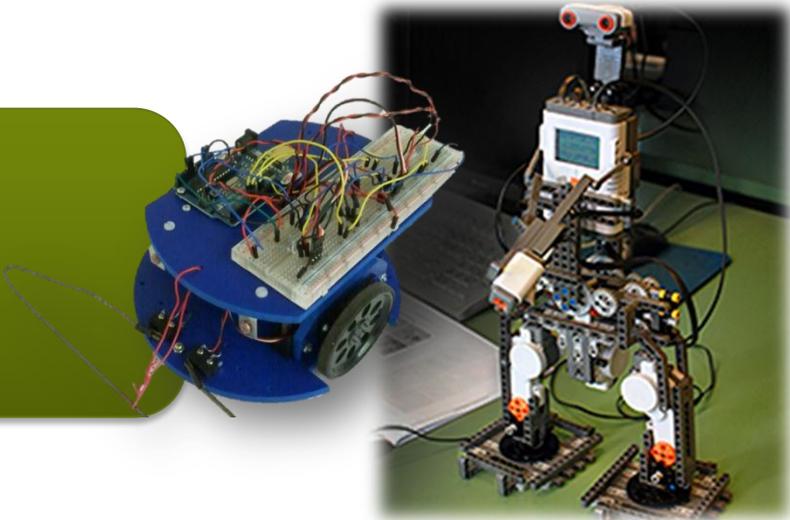
Two Avenues for Project-Based Learning



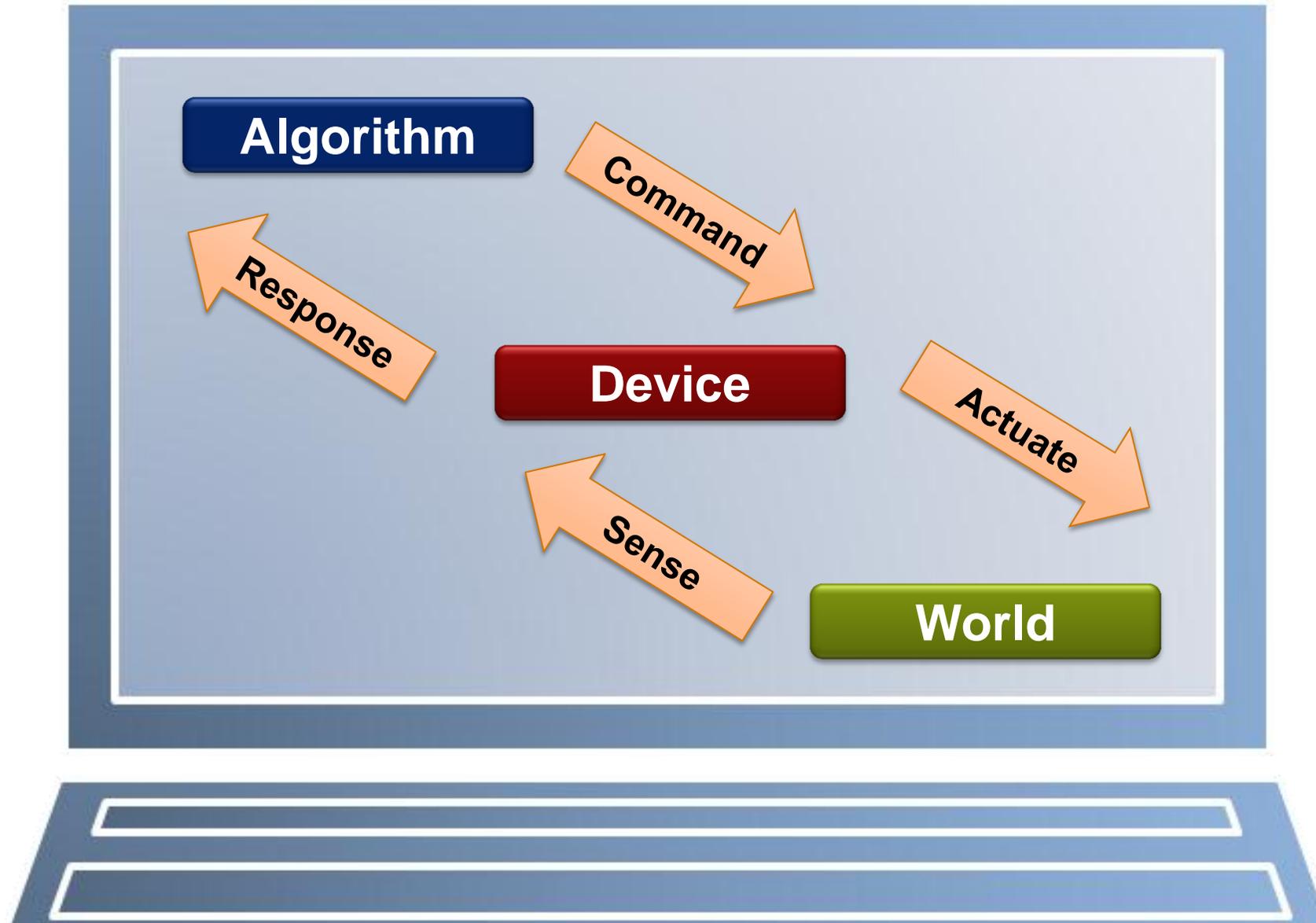
Simulation



Physical Interaction



Simulation

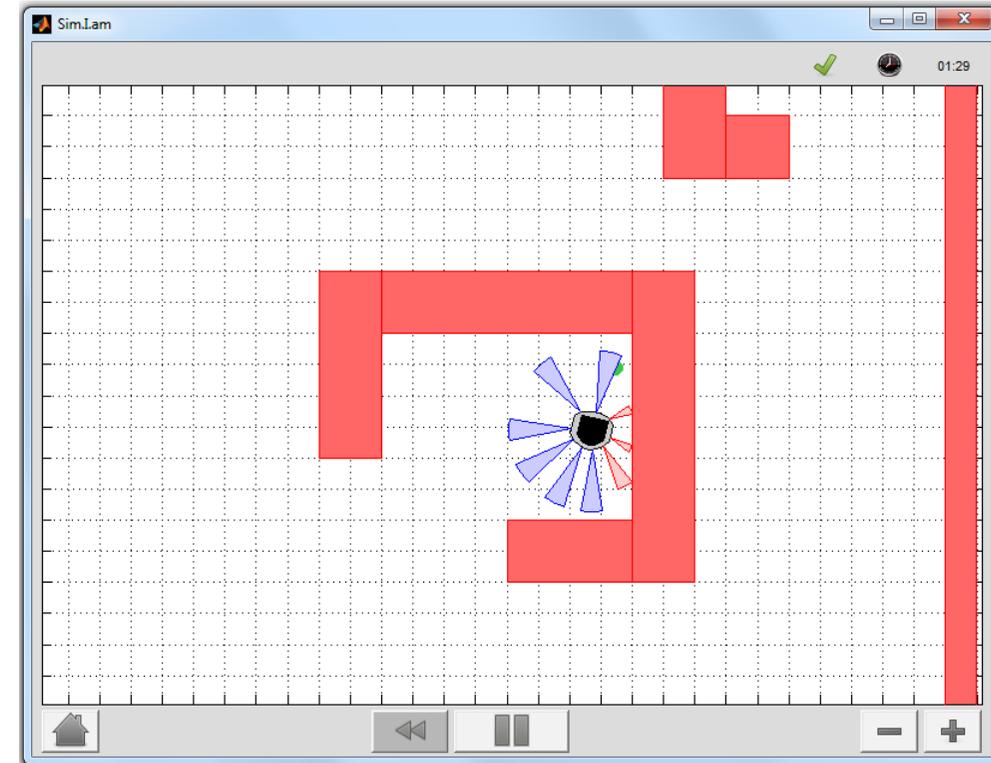


Simulation Demo 1: LEGO MINDSTORMS NXT

The image displays a MATLAB/Simulink simulation environment. On the left, a 3D model of a LEGO MINDSTORMS NXT robot is shown in a 'Vista view' window. The main workspace on the right contains a Simulink block diagram titled 'Self-Balancing Two-Wheel Robot'. The diagram shows a control loop where 'Guidance' (speed and turn) and 'Sensor Signals' are inputs to a 'Controller' block. The controller outputs 'Right Wheel Speed' and 'Left Wheel Speed' to a 'Hardware' block. The hardware block outputs 'R. Wheel Speed Simulated Sensor Signals' and 'L. Wheel Speed Actual Sensor Signals' to a 'Sim Out Coder' block, which then feeds back into the 'Environment Controller'.

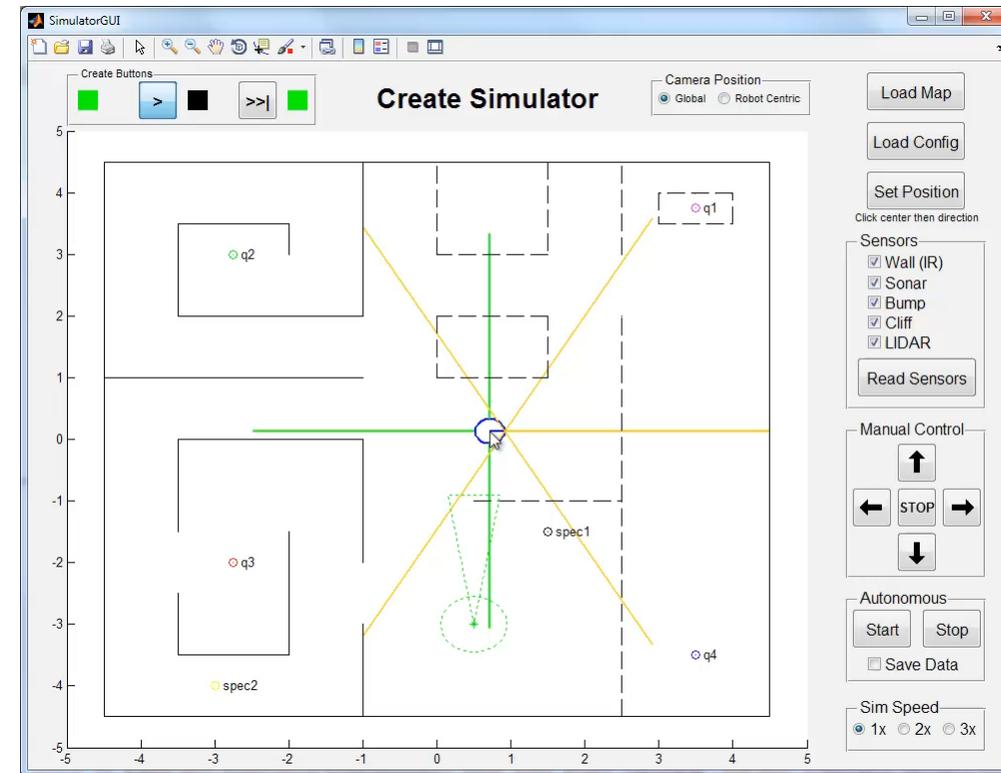
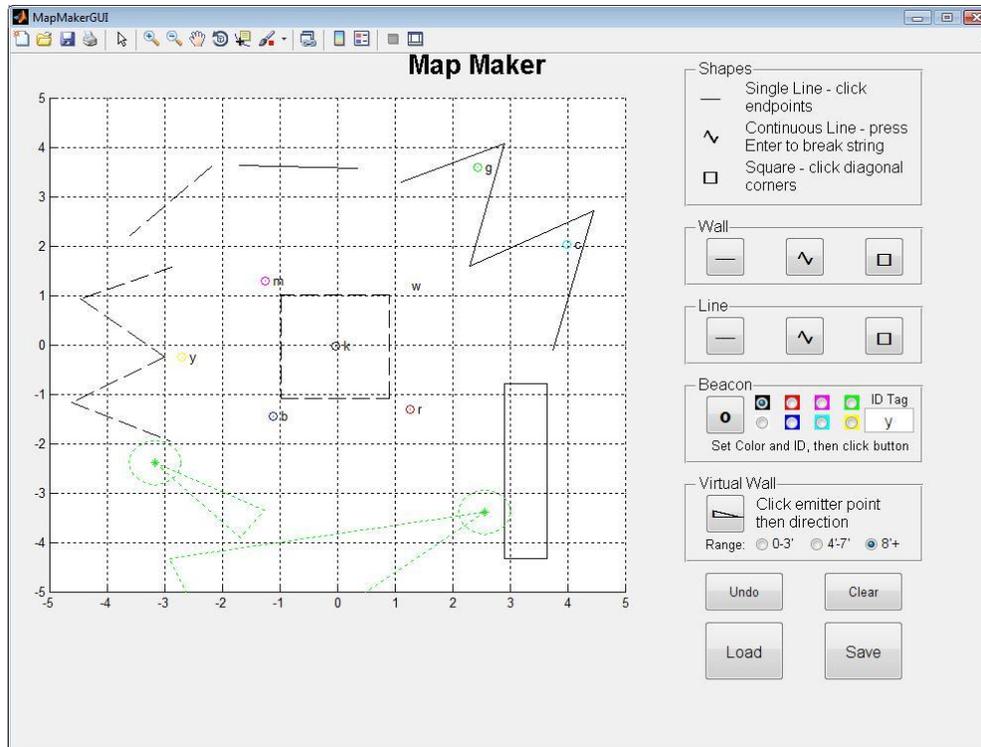
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Simulation Demo 2: Sim.I.am Robot Simulator (Georgia Tech)



GRITsLab, Georgia Institute of Technology: <http://jdelacroix.github.io/simiam/>

Simulation Demo 3: iRobot Create Simulator (Cornell)



Cameron Salzberger, K-Y Daisy Fan and Hadas Kress-Gazit, Cornell University:
<http://verifiablerobotics.com/CreateMATLABsimulator/createsimulator.html>

Simulation Demo 3: iRobot Create Simulator (Cornell)

**33% Students:
Better Understanding**

**42% Students:
Increased Motivation**

Fan, K.D.; Dimiduk, K.C.; , "Using the Matlab-based iRobot create simulator to engage introductory computer programming students in program development and observing computational errors," Frontiers in Education Conference (FIE), 2011 , vol., no., pp.S2G-1-S2G-6, 12-15 Oct. 2011

Simulation Benefits

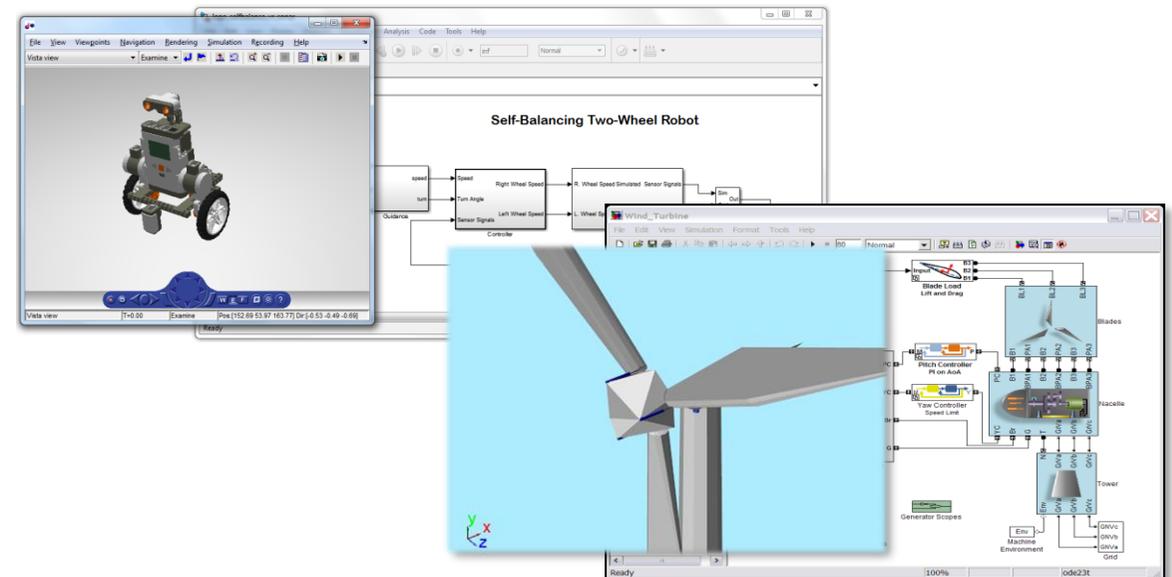
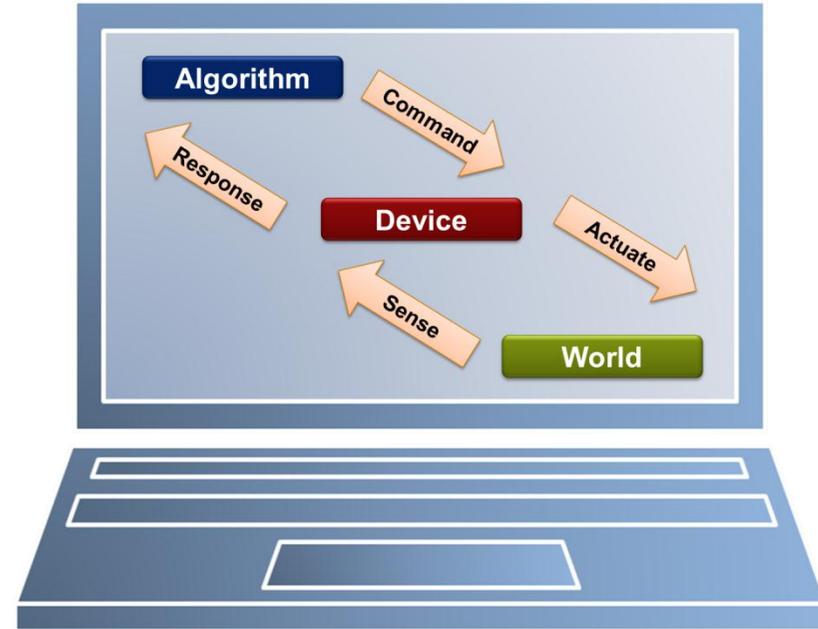
Inexpensive

Accessible

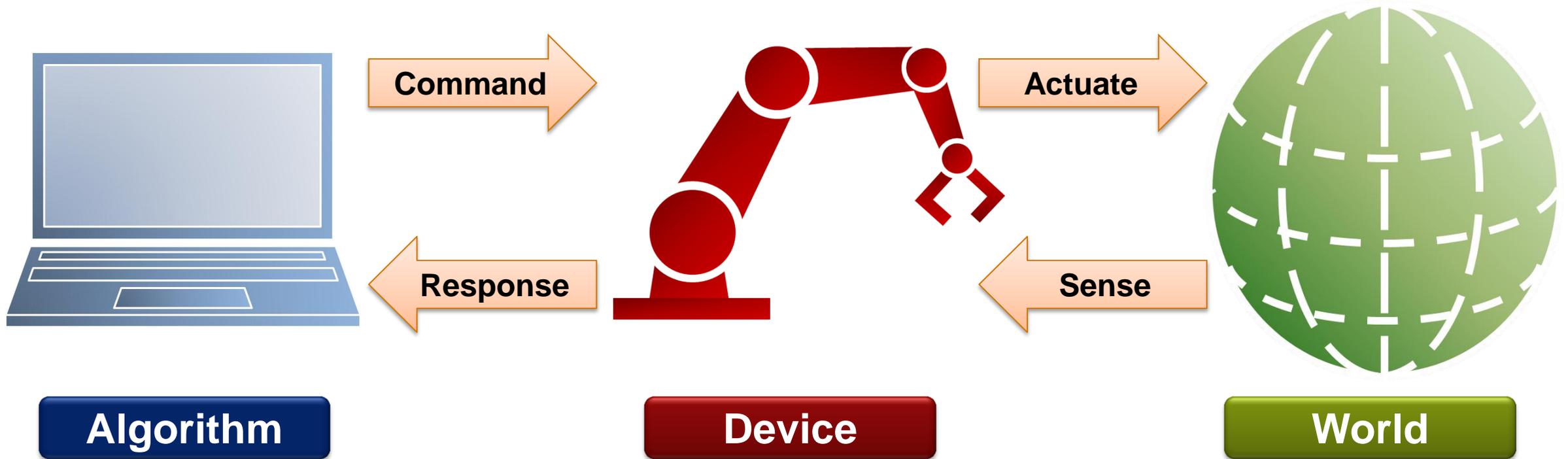
Robust

“What-If” Scenarios

“See” the Algorithms



Physical Interaction: a) Tethered



Tethered Demo 1:

Data Acquisition with Digilent Analog Discovery



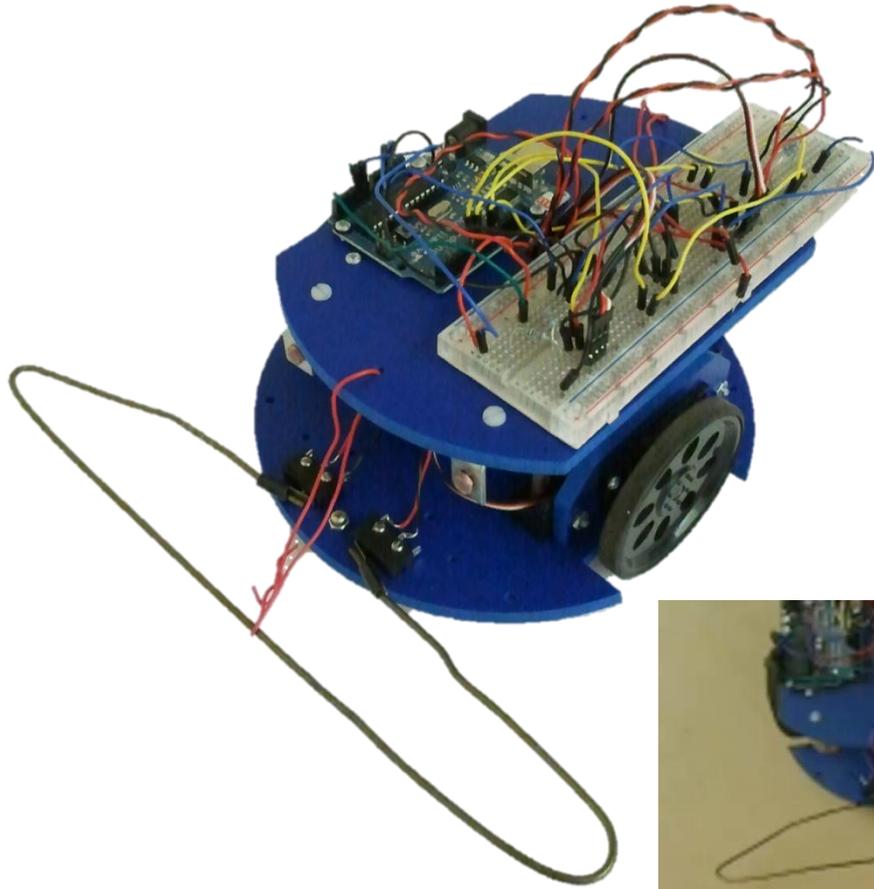
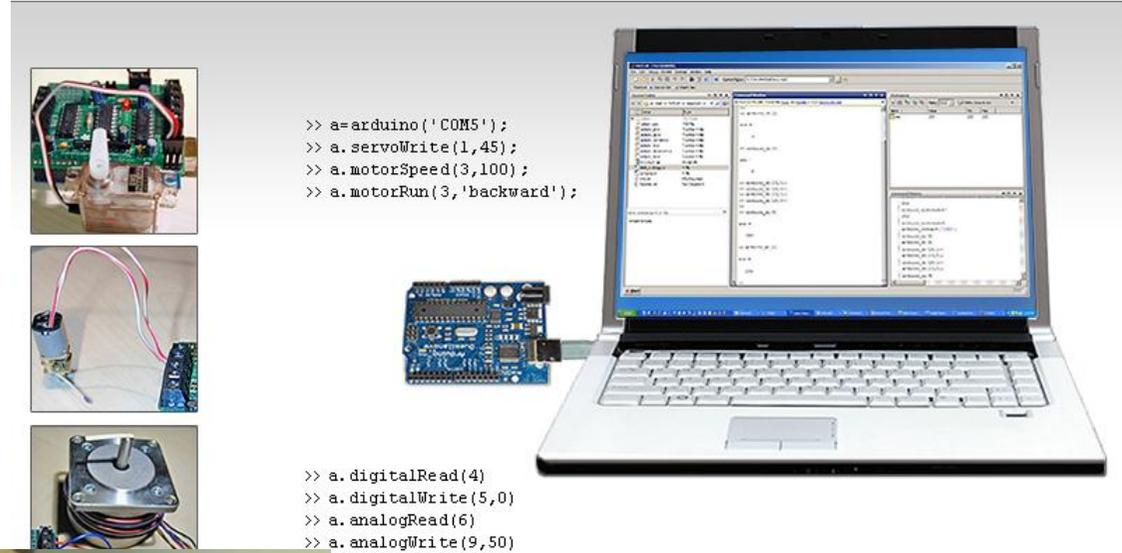
```
%% Create session with Digilent Analog Discovery, add analog input channel
s = daq.createSession('digilent');
ch = s.addAnalogInputChannel('ad1', 1, 'Voltage');

%% Set sampling rate and range
s.Rate = 300e3; % 300 KHz sampling rate for Analog Discovery hardware
s.Channels.Range = [-2.5 2.5]; % set Range

%% Collect 0.1 seconds of data
s.DurationInSeconds=0.1;
[data, timestamps] = s.startForeground;

%% Plot data
% 10 kHz external test signal with +/-500 mV amplitude is connected to the
% channel 1+ and 1- oscilloscope input pins of Analog Discovery hardware
plot(timestamps, data);
axis([0.03 0.035 -0.6 0.6]); % zoom in to show signal
xlabel('Time (seconds)'); ylabel('Voltage (Volts)');
```

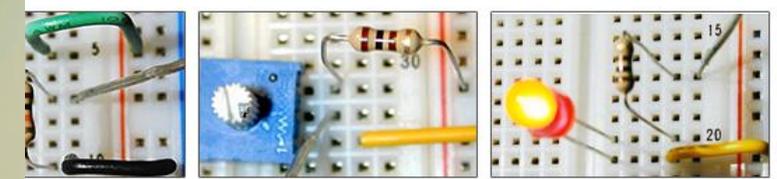
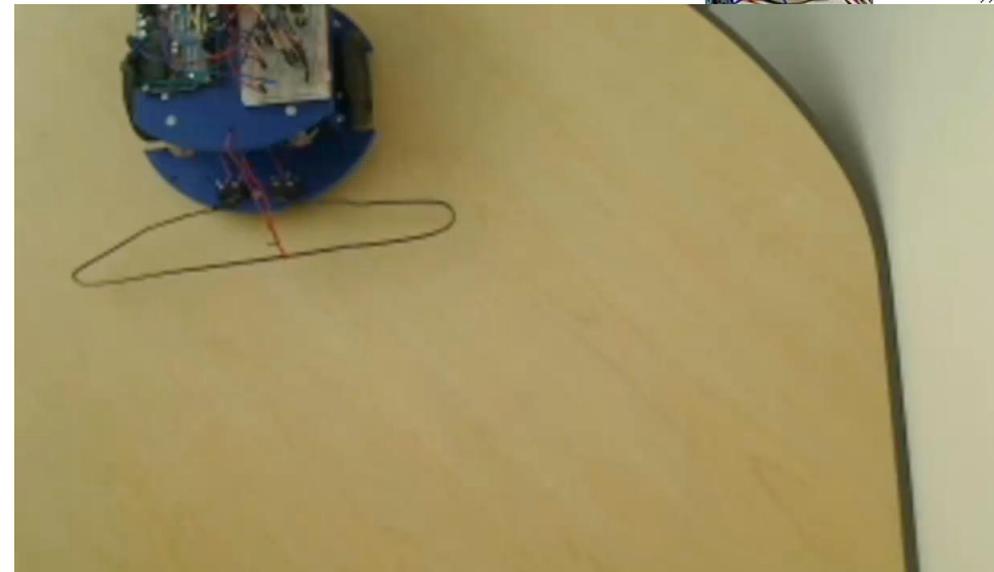
Tethered Demo 2: Arduino Support from MATLAB

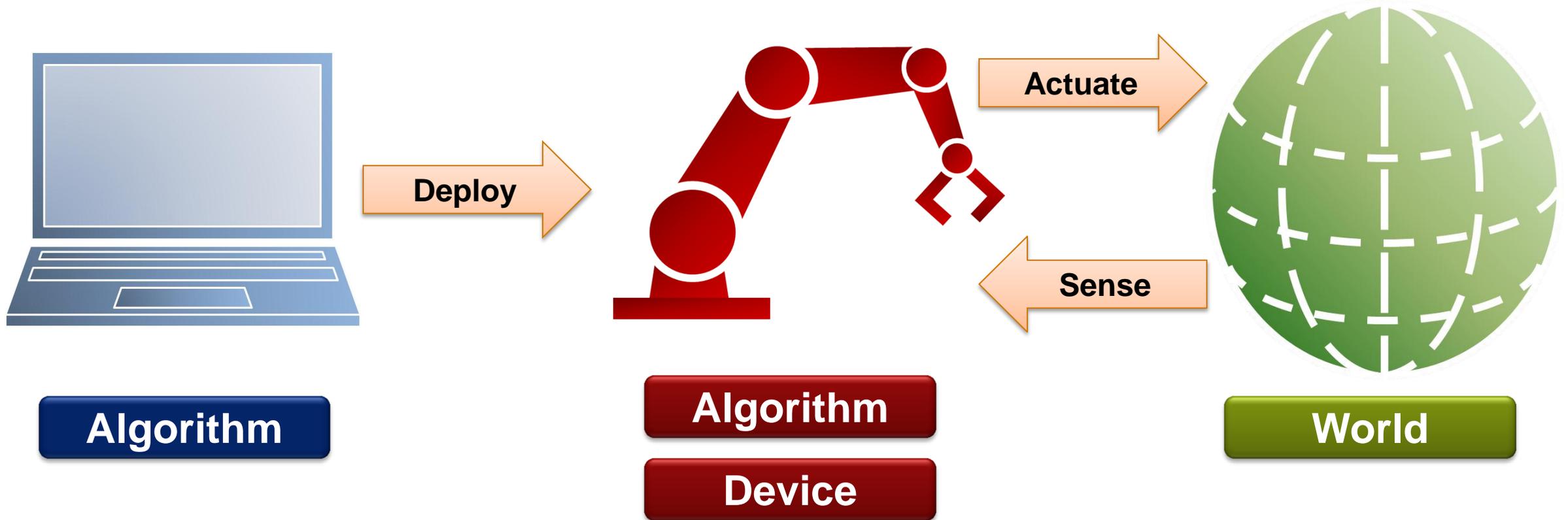
```

>> a=arduino('COM5');
>> a.servoWrite(1,45);
>> a.motorSpeed(3,100);
>> a.motorRun(3,'backward');

>> a.digitalRead(4)
>> a.digitalWrite(5,0)
>> a.analogRead(6)
>> a.analogWrite(9,50)
    
```



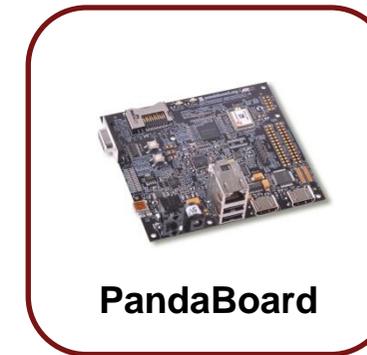
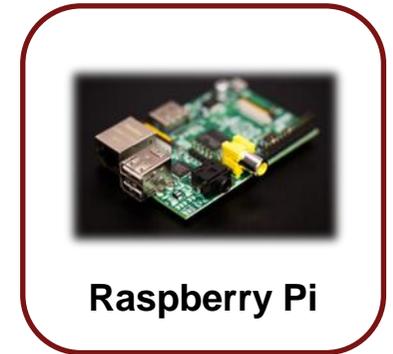
Physical Interaction: b) Embedded



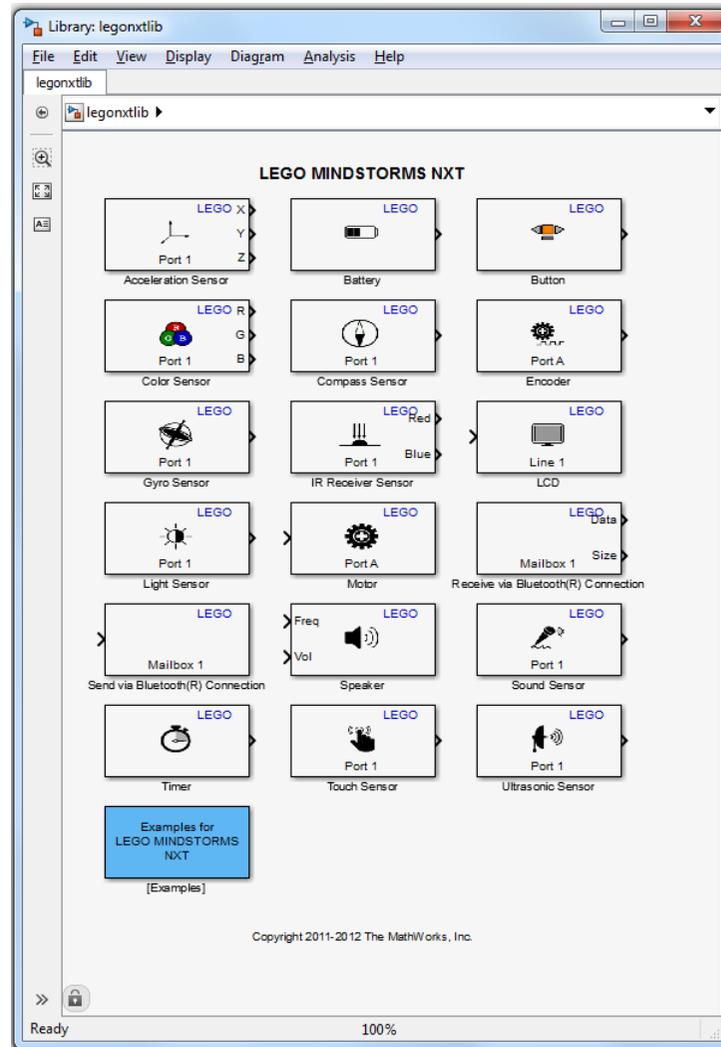
MATLAB/Simulink Target Hardware Support

The screenshot shows the MathWorks Hardware Support website. The search bar contains the text "tag:'Project-Based Learning'". The search results are displayed in a table with columns for the hardware name, a brief description, and the vendor. The results include:

| Hardware Name | Description | Vendor |
|--|--|-------------|
| Altera DE2 Support from Simulink | Digital circuit development platform for hardware design and verification | Altera |
| Arduino Support from MATLAB | Student-priced microcontroller board for introducing electrical engineering, motor control, and mechatronics | Arduino |
| Arduino Support from Simulink | Student-priced microcontroller board for introducing electrical engineering, motor control, and mechatronics | Arduino |
| BeagleBoard Support from Simulink | Low-cost, single-board computer designed for audio, video, and digital signal processing | BeagleBoard |
| Digilent Analog Discovery Support from MATLAB | Low-cost hardware development platform for analog circuit design using Data Acquisition Toolbox | Digilent |
| Digilent Atlys and Xilinx University Program Support from Simulink | Low-cost platform for real-world audio and video applications based on the Xilinx Spartan-6 FPGA | Multiple |
| Gumstix Overo Hardware Support from Simulink | Tiny computer on module (COM) designed for digital signal processing and product prototyping | Gumstix |
| Humusoft Lab Experiment Support from Simulink | Family of lab experiments for helping students apply control engineering principles with real-time dynamic systems | Humusoft |
| LEGO MINDSTORMS NXT Support from MATLAB | Widely used robotics platform for teaching introductory programming, robotics, and control design | Lego |
| LEGO MINDSTORMS NXT Support from Simulink | Create Simulink models that run directly on your robot | Lego |
| Microchip dsPIC Microcontrollers Support from Embedded Coder | Generate code optimized for dsPIC DSC. | Microchip |
| Microsoft Kinect Support from Simulink | Acquire data from Microsoft Kinect For Windows into Simulink. Kinect is a natural interaction device with an 3-D depth sensor, and 4-channel microphone. | Microsoft |



LEGO MINDSTORMS NXT Support from Simulink



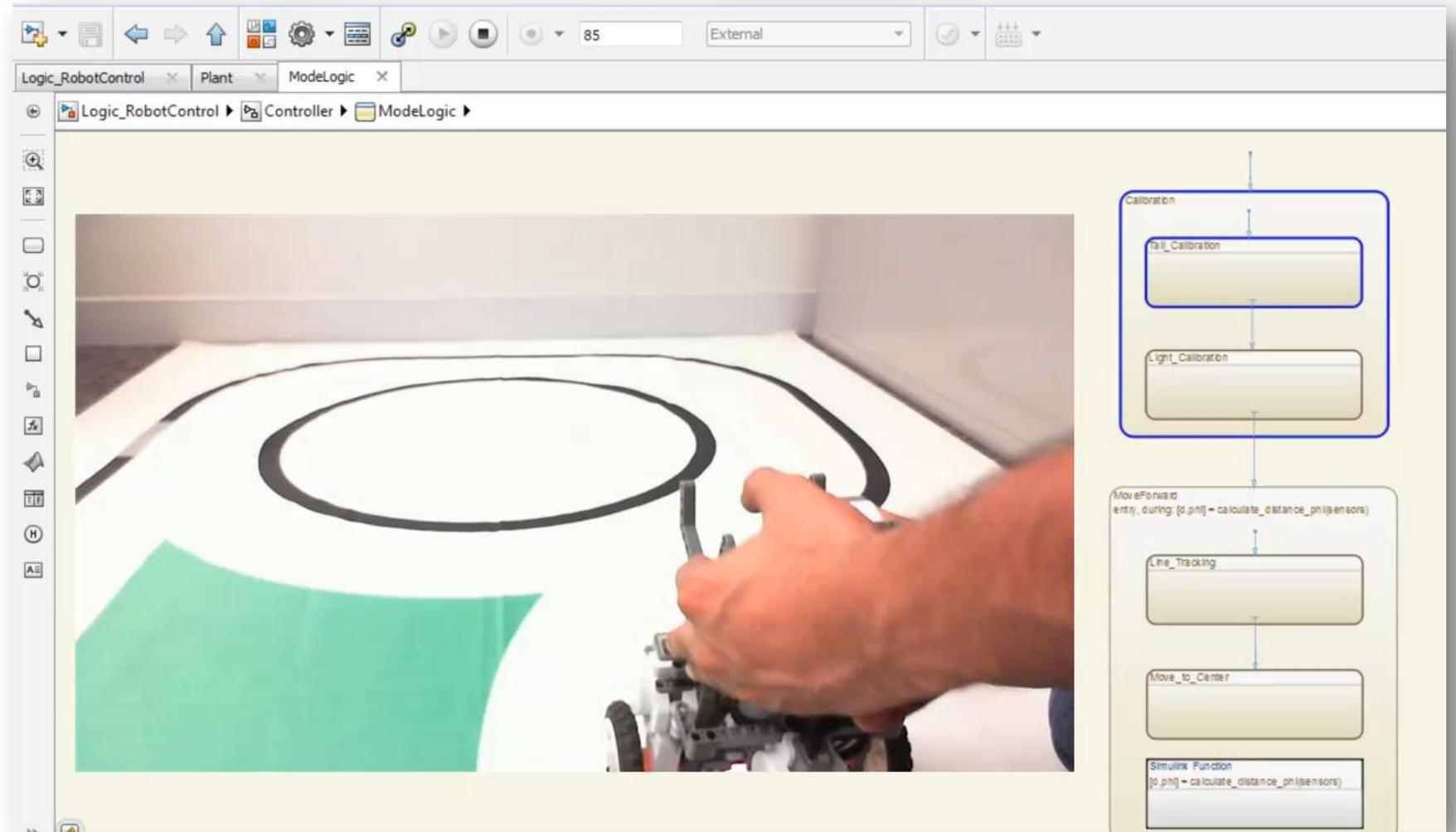
LEGO NXT Robot with State Machine Representation

Stateflow state machine

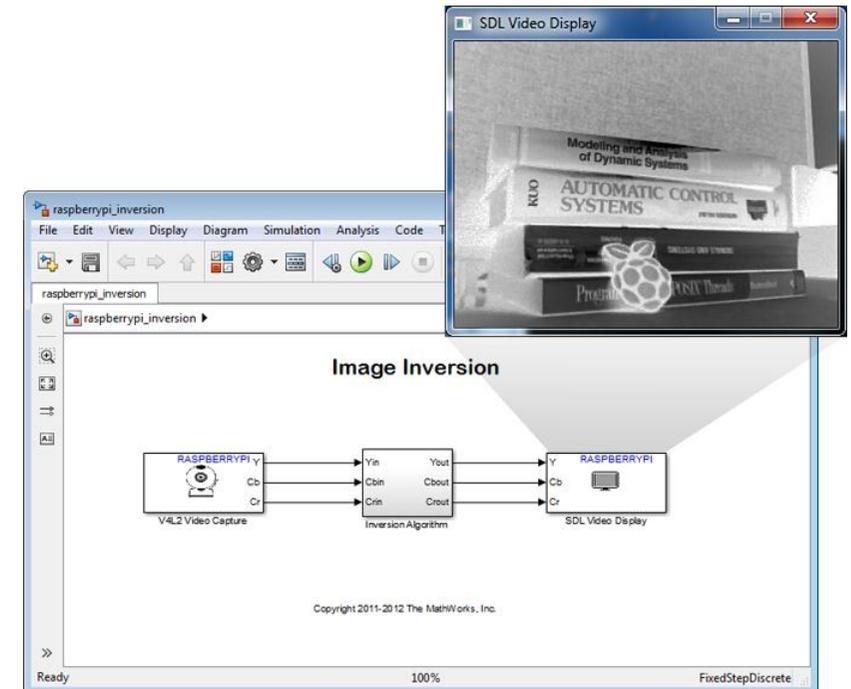
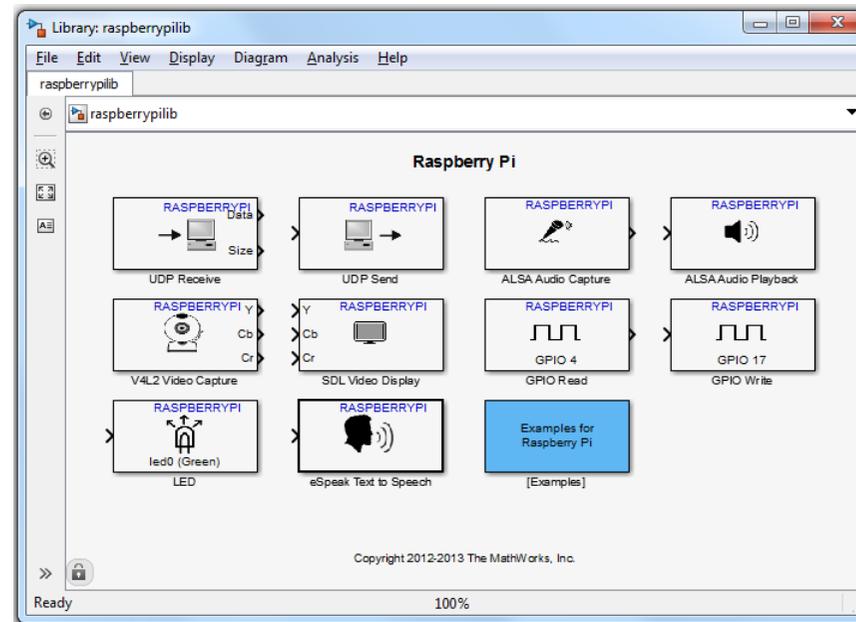
Easily design and deploy logic to the robot

Simulink external mode

Visualize and understand system behavior



Raspberry Pi (Model B) Support from Simulink



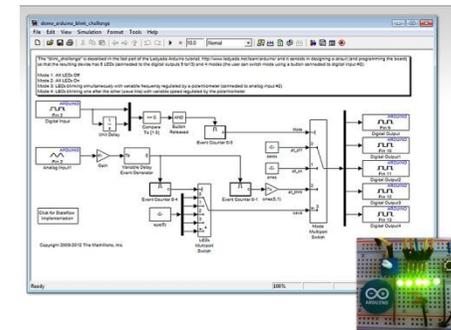
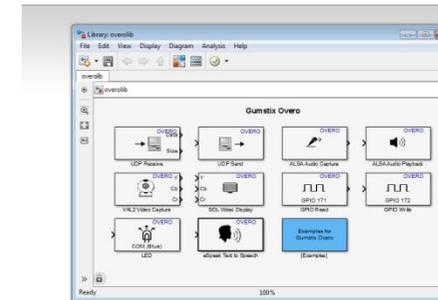
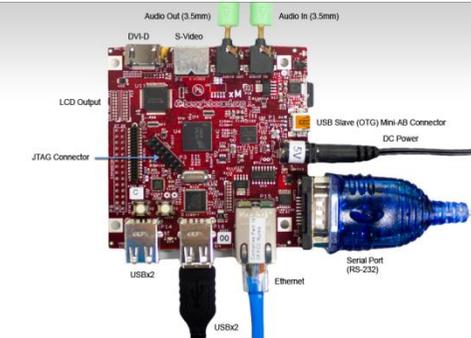
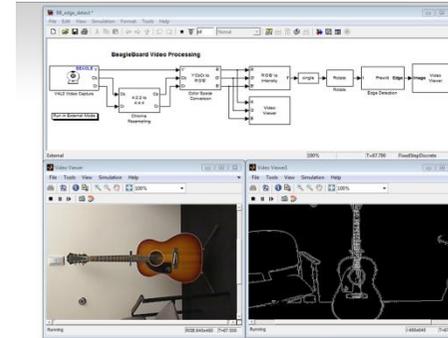
Simulink Hardware Support for Project-Based Learning

With just a click,
run your model on hardware

Selected Simulink Supported Target Hardware:

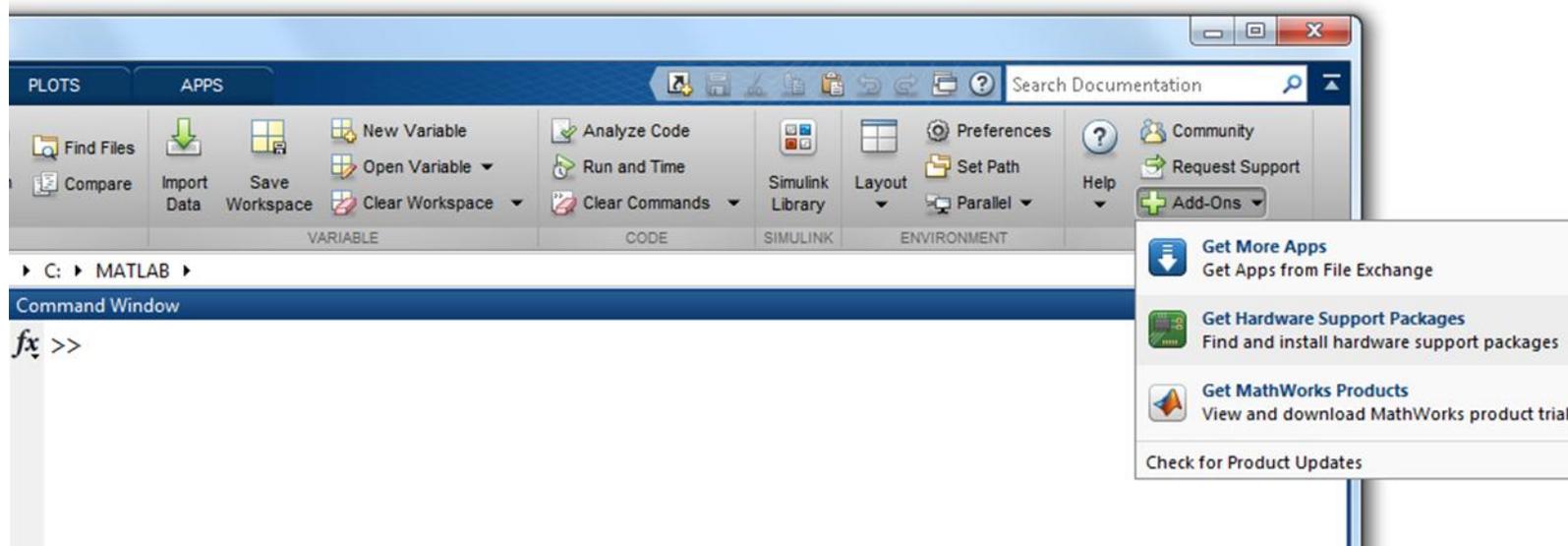
- Arduino® Uno (\$30), Mega 2560 (\$65)
- LEGO® MINDSTORMS® NXT (\$280)
- Raspberry Pi Model B (\$35)
- BeagleBoard-xM (\$150)
- PandaBoard (\$180)
- Gumstix® Overo hardware (\$180)

Also Available in Student Version



Get Simulink Hardware Support Packages

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



Get from the MATLAB Command Line: `>> targetinstaller`

Physical Interaction Benefits

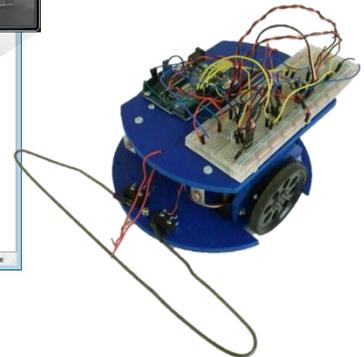
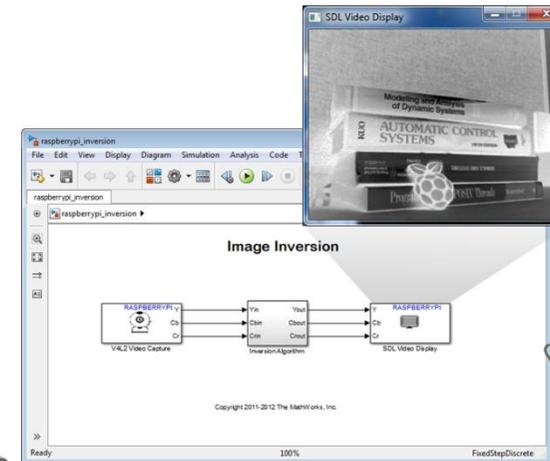
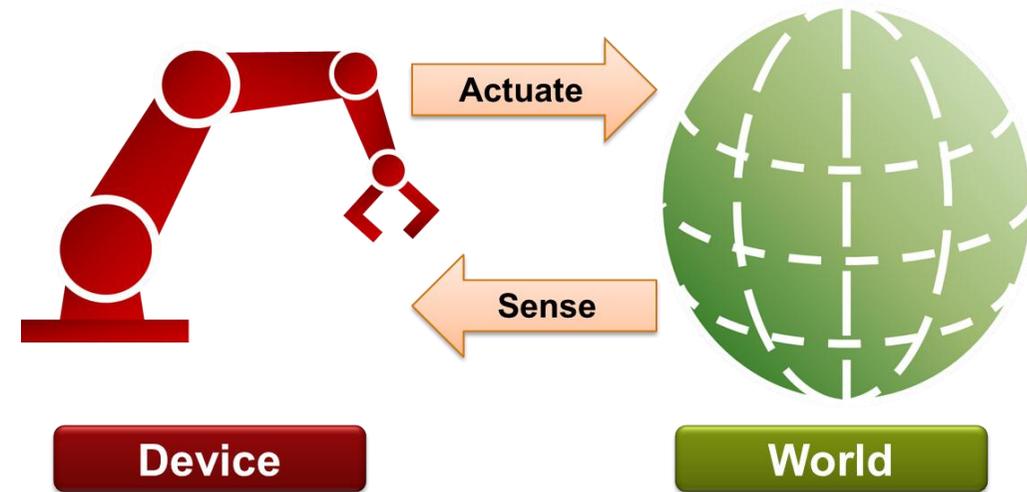
Accessible

High Fidelity

Unexpected Scenarios

Hands-On Learning

Engaging

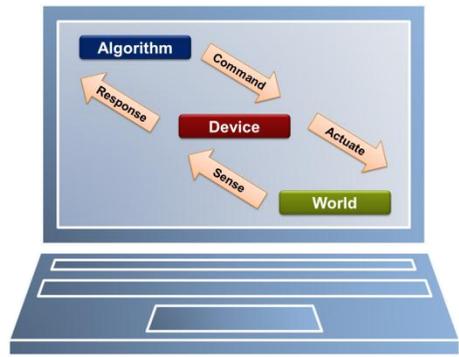
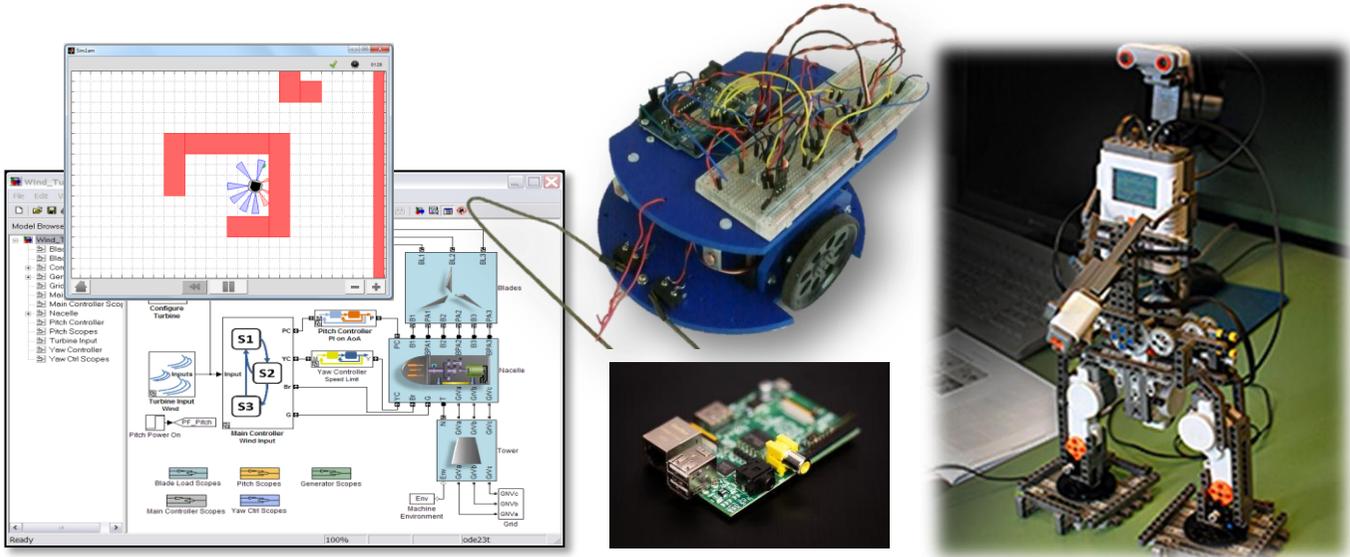


MATLAB/Simulink Solutions for Project-Based Learning

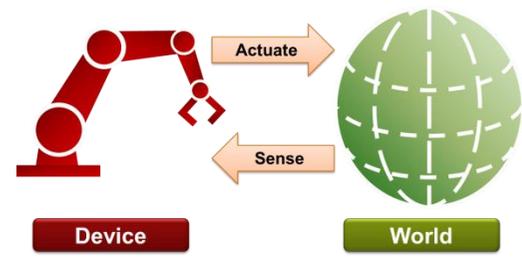
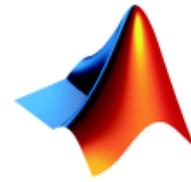
Project-Based Learning – Learning by Doing

MATLAB and Simulink:

- Both simulation and hardware solutions
- Target affordable hardware platforms
- Industry-standard workflow for engineering education



Simulation

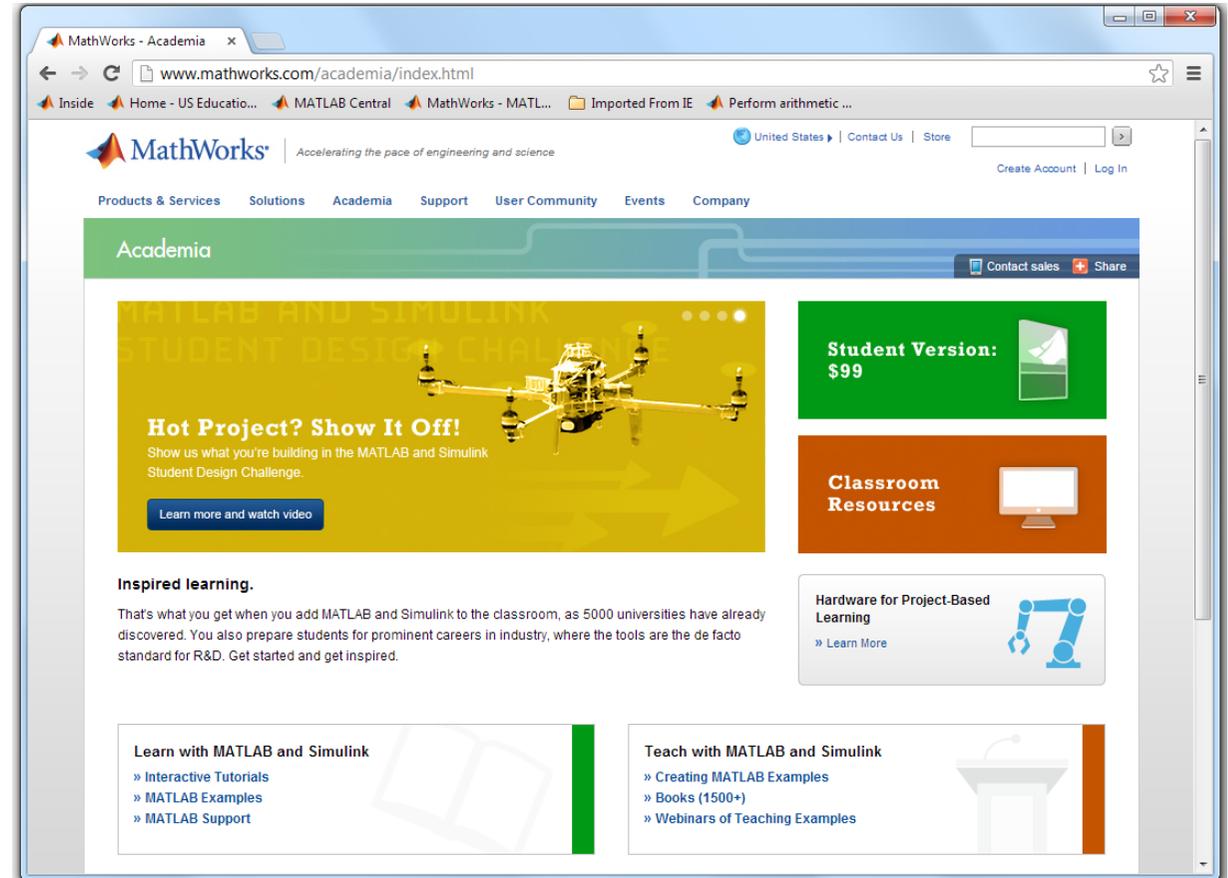


Physical Interaction

Additional Resources

www.mathworks.com/academia

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



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