Enabling Project-Based Learning

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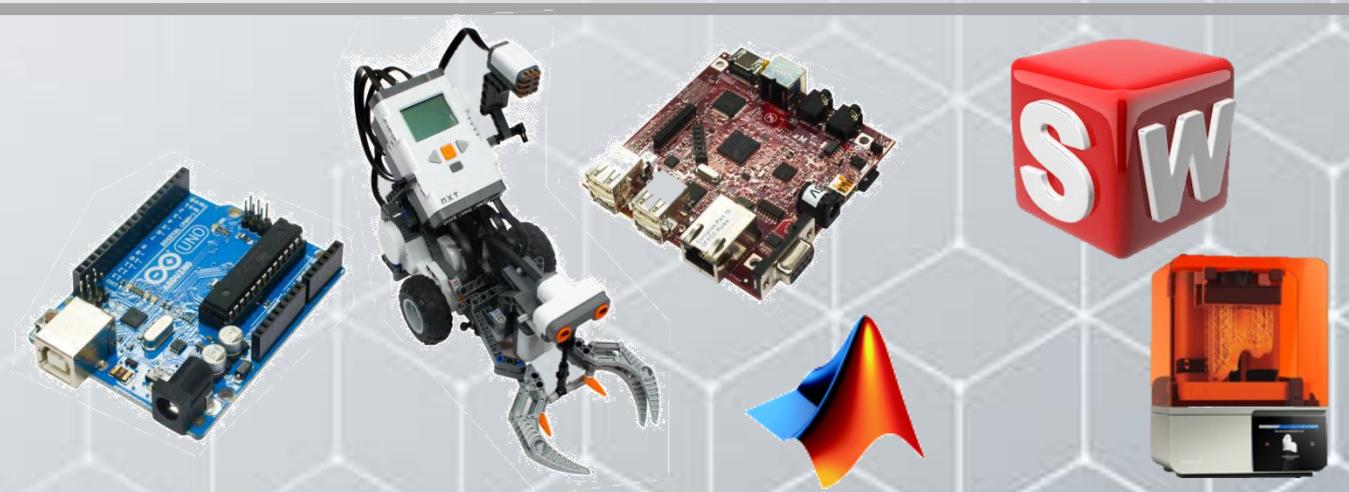


Agenda

- Project-Based Learning (PBL): What is it? Why is it important?
- How do we enable PBL?
- How to start using PBL
- University Examples
- Q&A

“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
MIT

Keynote National School Boards Association Technology and Learning Conference 1994

What does industry think?

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

UK Customer Survey

Understand Principles of Verification and Validation

Multi-Domain Physical Model Simulation

Good at Abstraction and Big Picture Thinking

Understand Real-World Problems

Mathematical Models, Transformations, Invariants

Continuous, Discrete & Hybrid Systems

Competent in Modelling & Simulation

Appreciate Safety & failure modes

Implement & Deliver Solutions

Collaborative Team / Design & Implementation Guidelines

Rolls-Royce

AIRBUS Leading aircraft manufacturer

JAGUAR

LAND ROVER

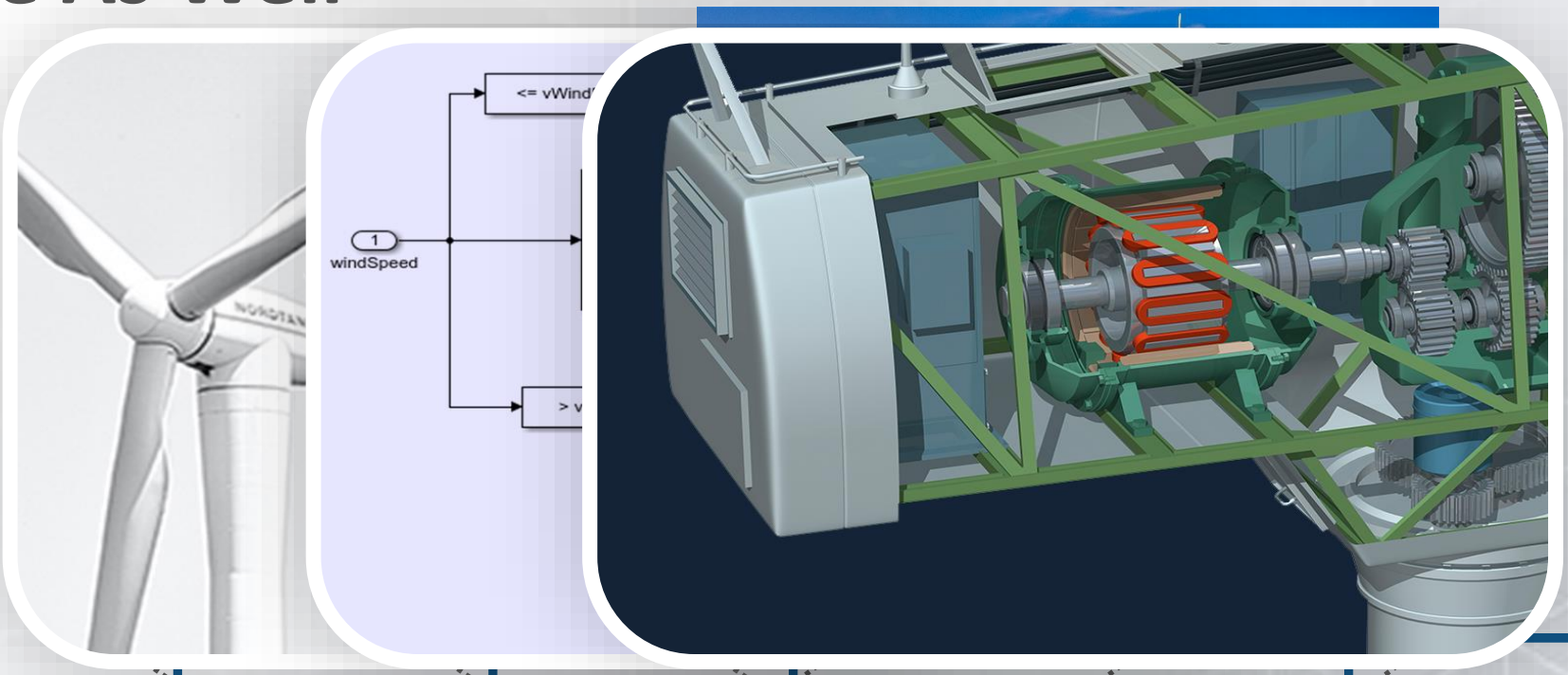
SELEX GALILEO

BAE SYSTEMS

THALES

ALSTOM

Engineering Systems are Multidomain = Curricula Should Be As Well



Aerospace

Mechanical

Electrical

Computer

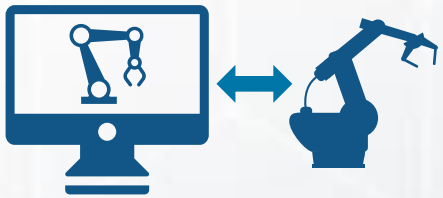
Chemical

Civil

Environmental

Systematics

Emerging Trends for Multidomain Engineering Systems



Robotics

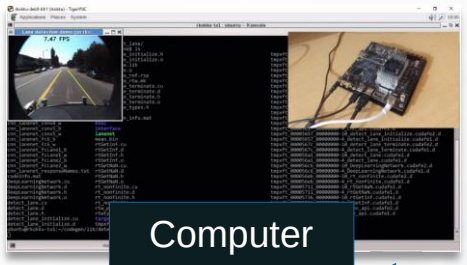
Connectivity

Artificial Intelligence

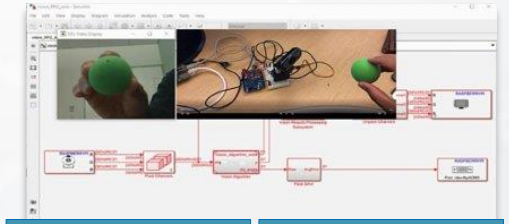
Electrification

We collaborate with engineering education institutions to address these trends in curriculum.

Teach Robotic Systems Design

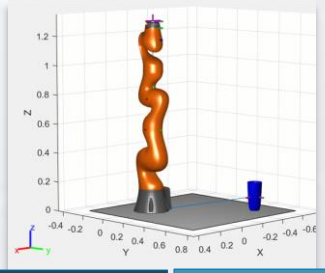


Computer vision



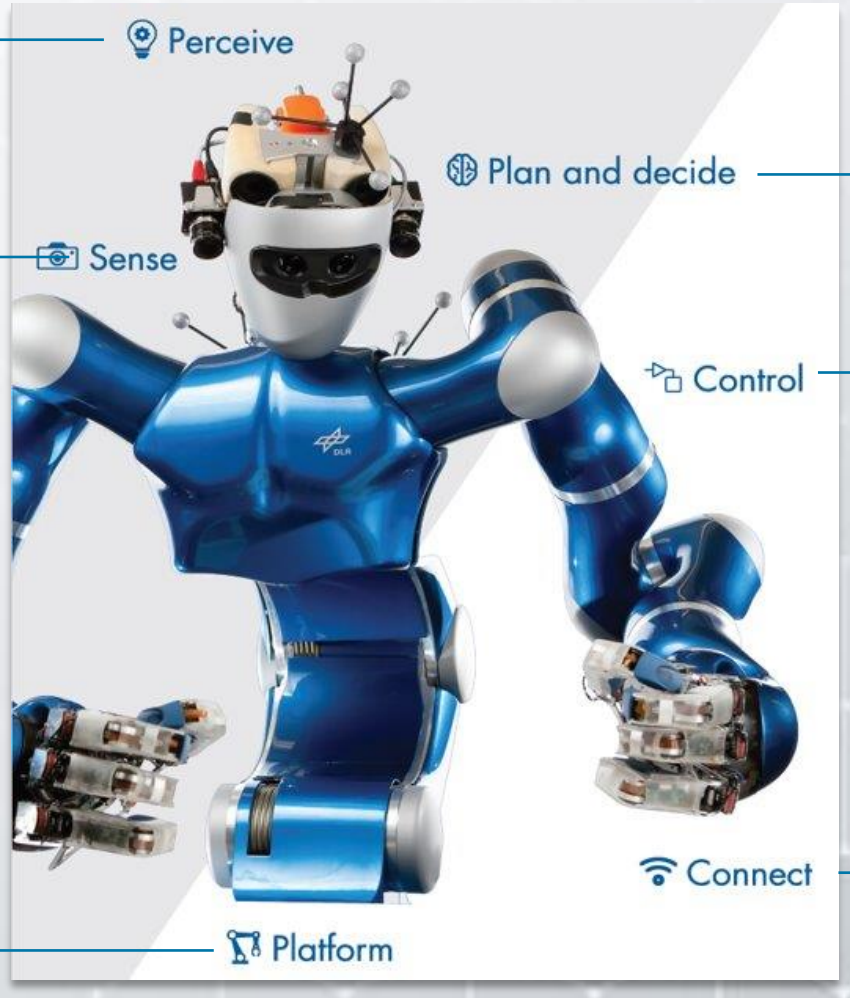
Electronic instrument.

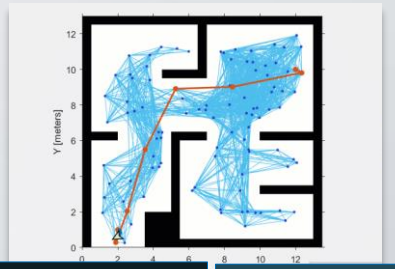
Sensors & actuators



Industrial robots

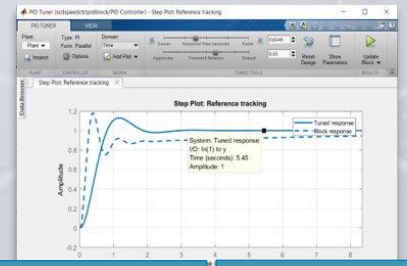
Mechanical engineering





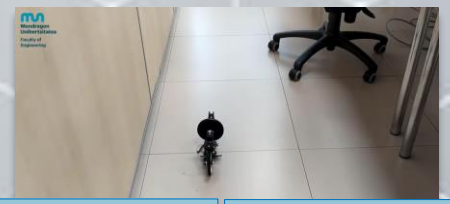
Intelligent decision

Mobile robots



Control engineering I

Control engineering II



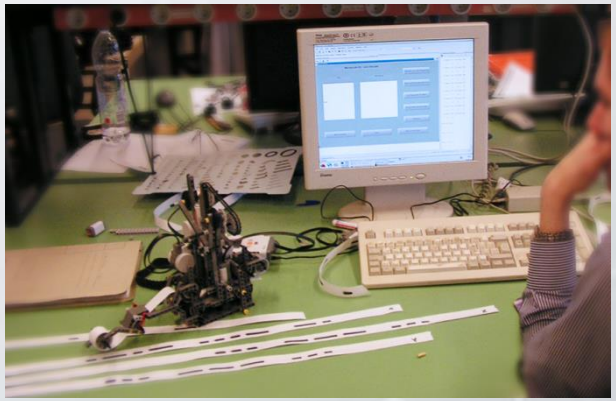
Telemmatic syst. design

Communic. protocols

Project-Based Learning

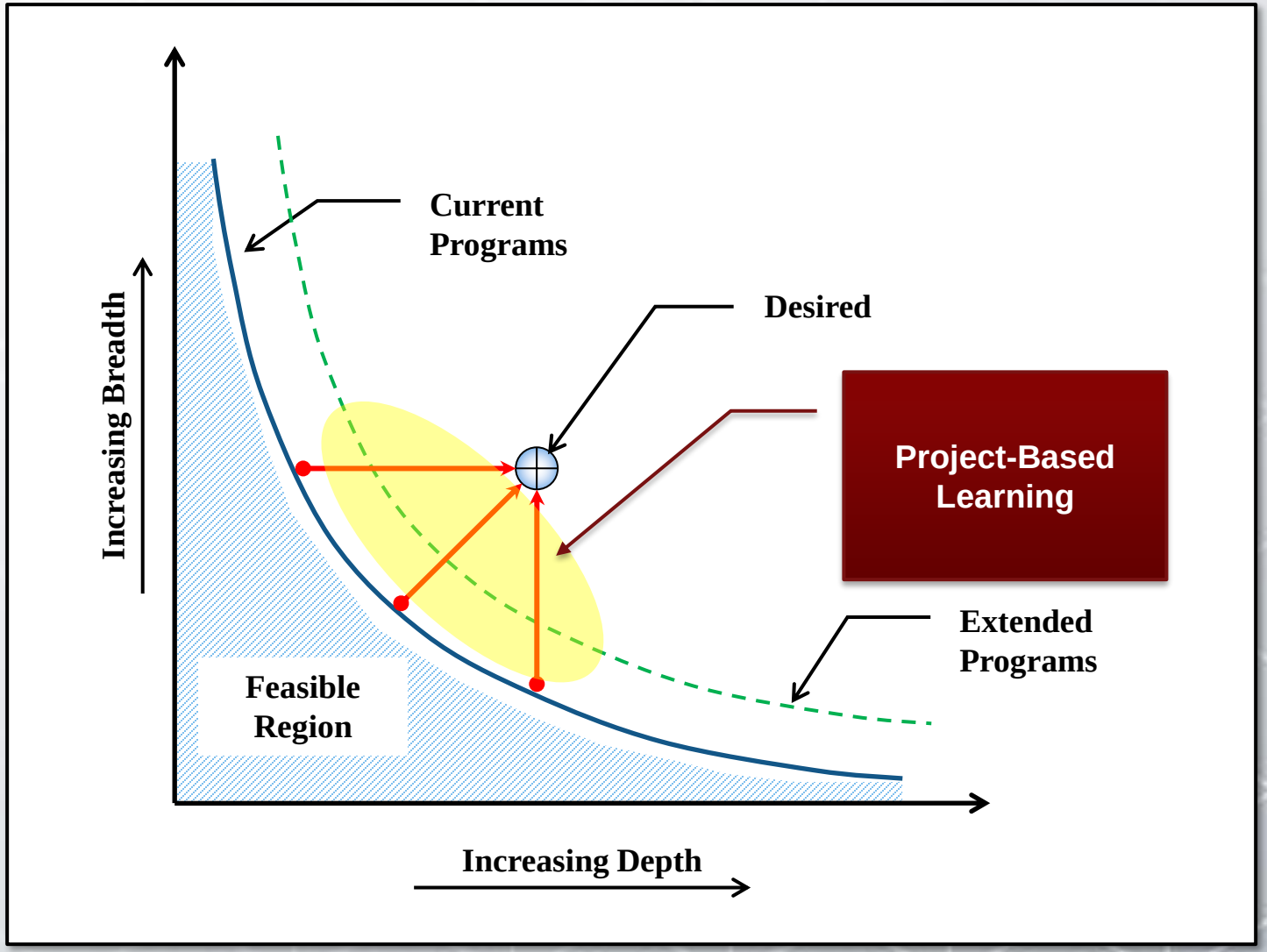
Project-Based Learning

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**

Challenge: Trade-offs in Engineering Curricula



Who are we - Systematics

Systematics

Systematics' Mission

Systematics is a technology company that delivers and integrates solutions for digital transformation in the areas of science, engineering and manufacturing.

- Main industries: Aerospace and Defense, Electronics and Semiconductors, Med. Devices)
- Customers (~ 1000):

  - Large accounts like: IDF. Rafael. IAI, Elbit, Intel, Apple, Nvidia, Qualcomm, Applied Materials, …

  - 50 Accelerators, 400 startups

  - All leading academic institutions (17 of them use Open Access license)

- Examples of projects: Space IL, Iron Dome, Armored Shield protection, UAV projects, Mobileye autonomous driving, GM autonomous parking system, cutting-edge Medical Robotics, ….)

Areas of Specialization

3D CAD / PLM

Dassault Systèmes
> SOLIDWORKS > ENOVIA > CATIA
> 3DEXPERIENCE

Altium

Technical Computing & Model-Based Design

MathWorks
> MATLAB & Simulink

Geographic Information Systems (GIS)

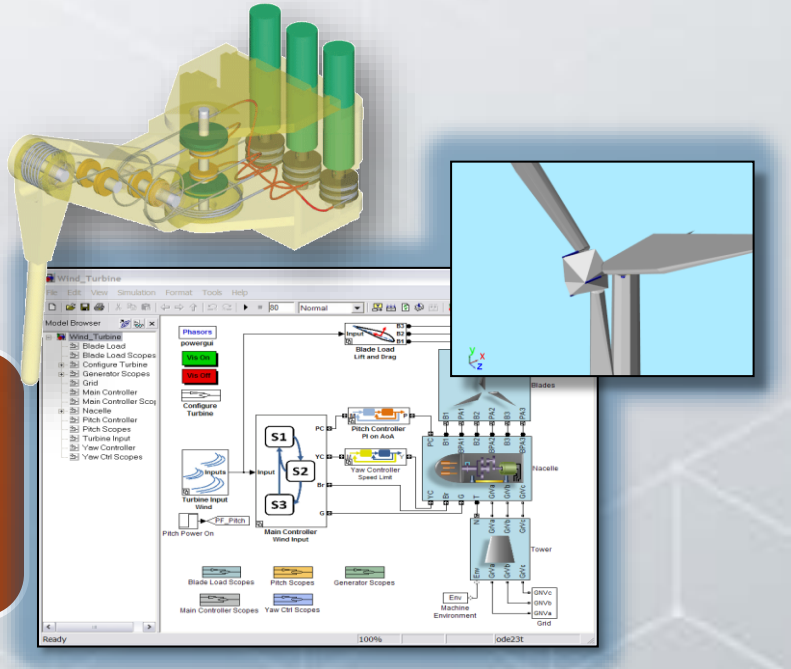
ESRI,
Schneider Electric,
Here, Maxar, Ecopia

3D Printing

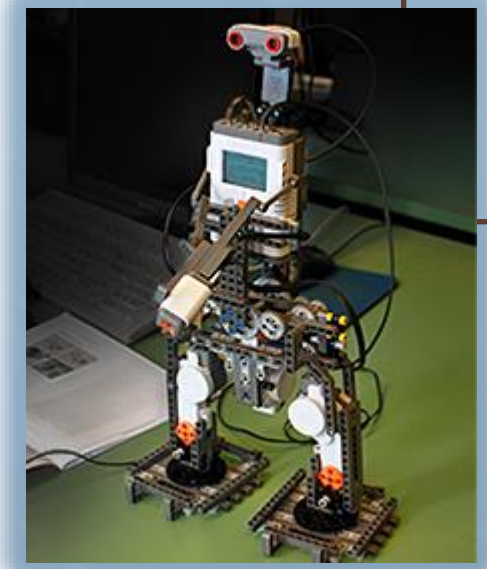
HP
Formlabs
Markforged
BCN3D

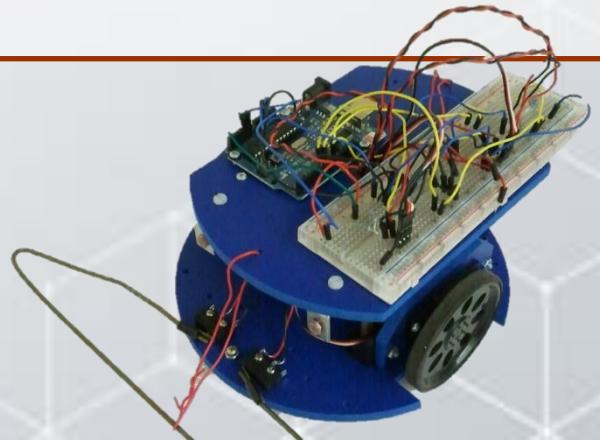
Solutions for Project-Based Learning

Simulation



Hardware





```
% create arduino object and connect to board
if exist('a') && isa(a,'arduino') && isvalid(a),
    % nothing to do
else
    a=arduino('DEMO');
end

% initialize pins
disp('Initializing Pins ...');

% sets digital input pins
a.pinMode(2, 'INPUT');
a.pinMode(3, 'INPUT');
```

Hardware Support for Project-Based Learning

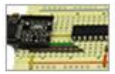
MathWorks | Accelerating the pace of engineering and science

Products & Services | Solutions | Academia | Support | User Community | Events | Company

Hardware for Project-Based Learning

Use MATLAB and Simulink with a variety of hardware platforms for project-based learning. Options range from student-owned hardware to versatile solutions for controls, mechatronics, robotics, and signal processing in classroom labs.

Arduino
Student-priced microcontroller board for introducing electrical engineering, motor control, and mechatronics



Machine Science Microcontroller Kits
Low-cost kit with Atmel ATmega168 microcontroller for building circuits on a solderless breadboard

BeagleBoard
Low-cost, single-board computer designed for audio, video, and digital signal processing

Microchip dsPIC Microcontrollers
Low-cost boards suitable for controls, signal processing, and custom prototyping

Digilent Atlys
Low-cost platform for real-world audio and video applications based on the Xilinx Spartan-6 FPGA

PC-Based Vision Systems
Imaging hardware for machine vision, including generic webcams, industrial cameras, and frame grabbers

dSPACE ACE Kits
Controller boards and software tools for developing and testing real-time control systems

Quanser
Hardware experiments, data acquisition cards, and Simulink models for teaching controls, mechatronics, and robotics

Education Real-Time Target

Arduino

Lego NXT

BeagleBoard

PandaBoard

RaspberryPI

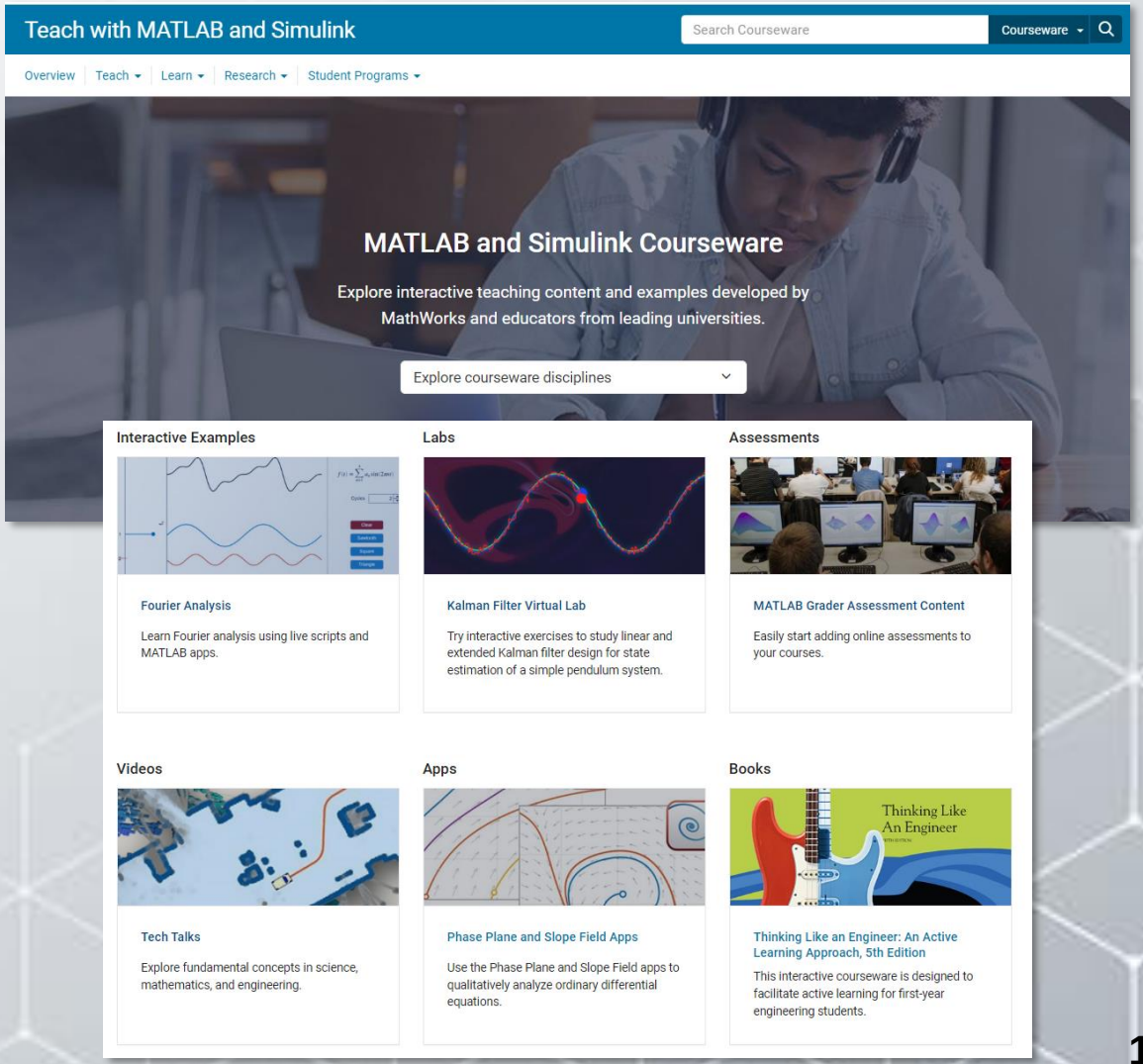
+ ANDROID
+ SDR
+ ROS
+ Quadcopters …

Existing Capabilities and Resources for PBL

Interactive teaching content

Visit our courseware for downloadable course materials including demos, tutorials and project-based learning exercises:

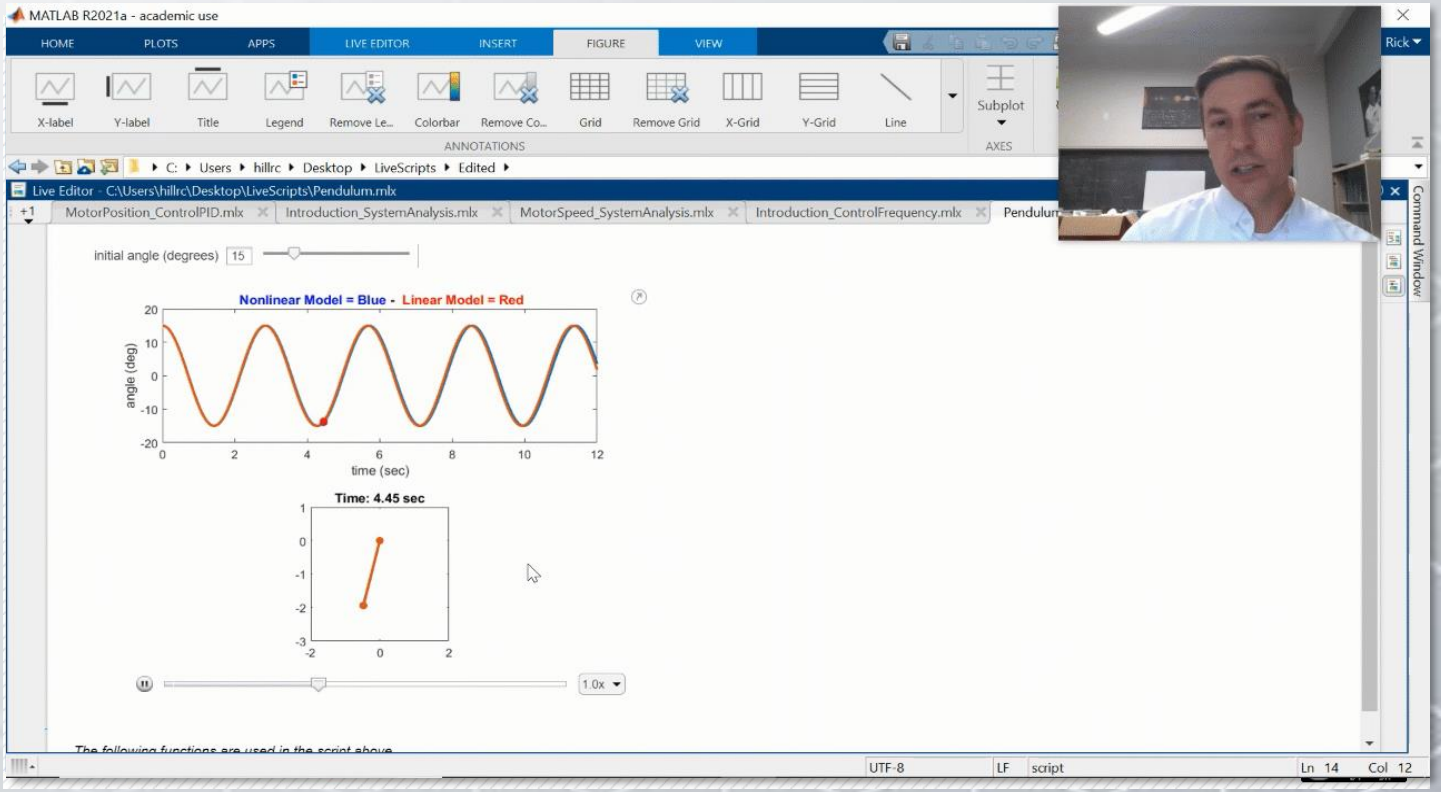
- Awesome Robotics with MATLAB & Simulink
- Control Tutorials with MATLAB & Simulink
- Robotics Playground
- Applied Autonomous Robots I
- Applied Autonomous Robots II
- Mobile Robots Control
- Reinforcement Learning with MATLAB
- Electromechanical Engineering Systems
- MATLAB and Simulink ROS Tutorials

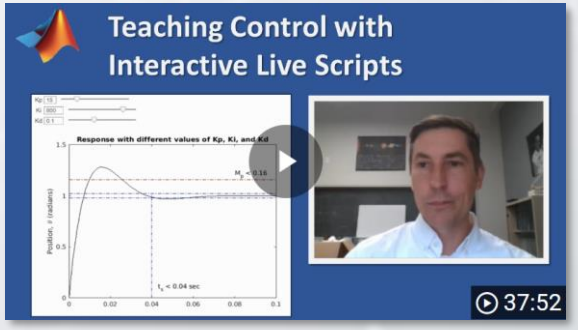


Reuse courseware developed by universities

Control tutorials by University of Michigan, Carnegie Mellon University and University of Detroit Mercy

- Using Control tutorials students can practice system modeling and analysis, control design and tuning using various examples
- Run interactive control tutorials in your browser
- Check out this webinar by Prof. Richard Hill for an overview of teaching modeling and controls with live script control tutorials





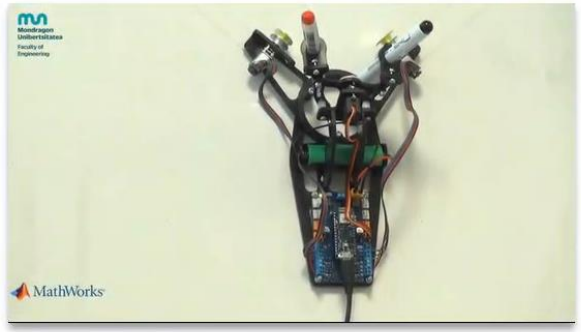
Use low-cost hardware for project-based learning

Arduino Engineering Kit curriculum by Mondragon University

- C01_Kinematics
- C02_Math_computations
- C03_Closed_lool_control
- C04_Model-based_design
- C05_Simulations
- C06_Robot_movement
- C07_Differencial_drive
- C08_Path_following_algorithm
- C09_Image_processing
- C10_Wireless_networks
- C11_Coordinate_geometry
- C12_Trigonometry

Drawing robot

Autonomous rover



File Exchange

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Mondragon Unibertsitatea Faculty of Engineering

MathWorks

ARDUINO-ENGINEERING-KIT

version 1.0.1 (78.5 MB) by Gaizka Bellido Sanjulian

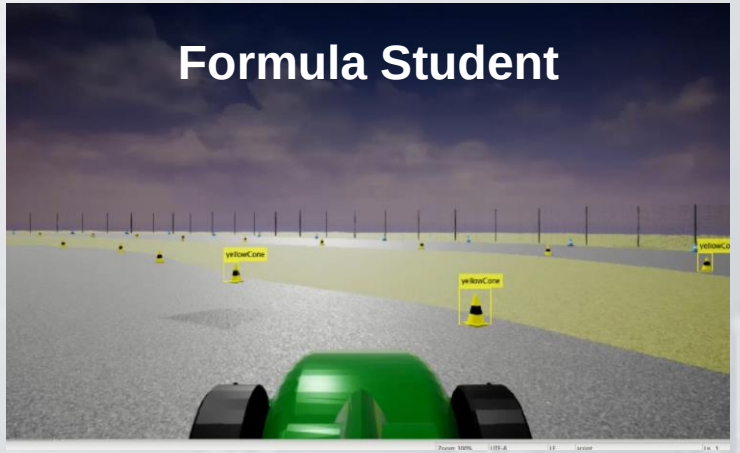
Download this example from GitHub or File Exchange!

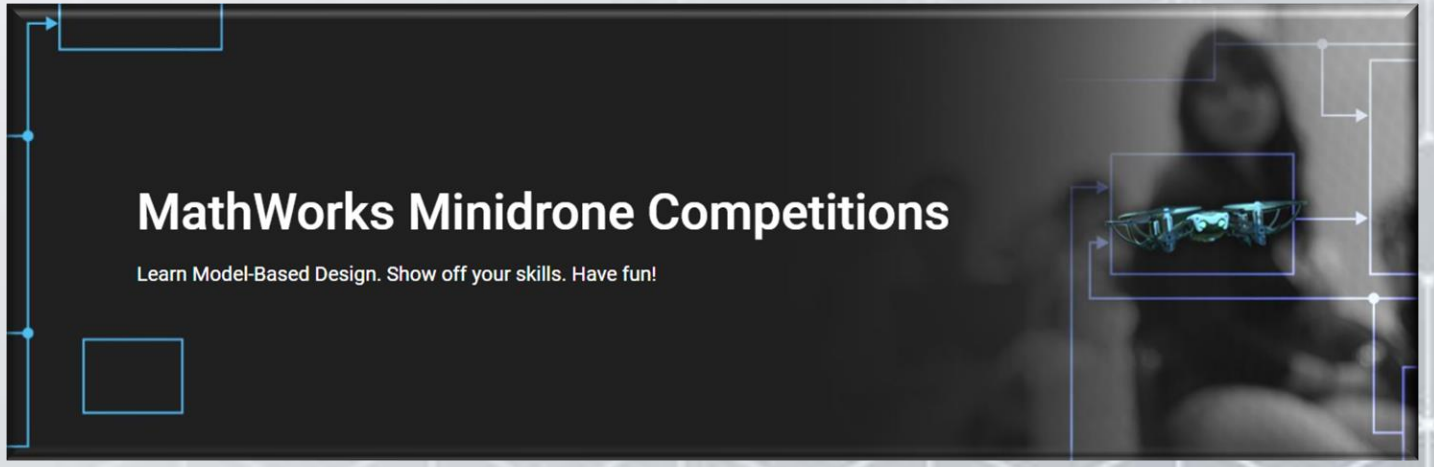
Encourage students to put their knowledge to the test

Robotics competitions supported by MathWorks

Robotics

- BEST Robotics
- Brain-Computer Interface
- Collegiate Wind Competition
- European Rover Challenge
- FIRST Robotics
- Intelligent Ground Vehicle Competition
- Korea Semiconductor Design Challenge
- Micromouse Contest
- National DD-Robocon
- Pan-African Robotics Competition
- Road2FEI
- RobAFIS
- ROBO-ONE
- RoboCup
- RoboCupJunior
- RoboNation Competitions
- RoboRace
- Singapore Autonomous Underwater Vehicle Challenge
- VEX Robotics
- World Robot Summit



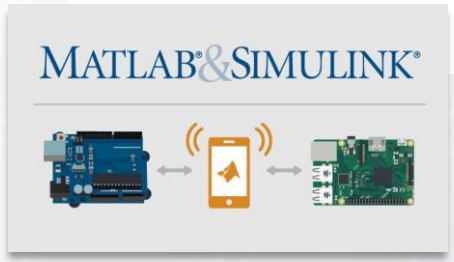


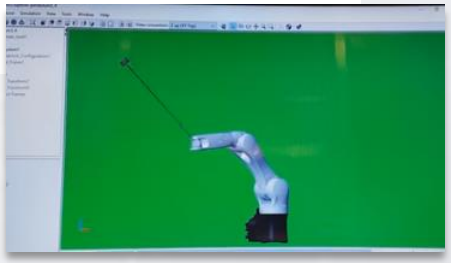
Visit MathWorks' student competitions webpage

Challenge your students

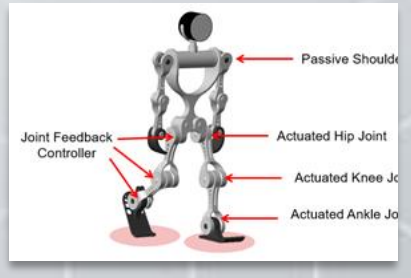
Ideas for research projects, undergraduate/postgraduate final projects…

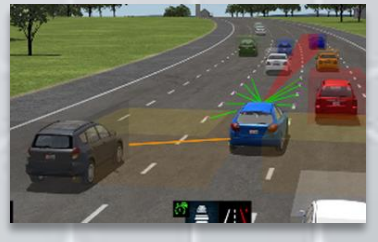
SIMULINK STUDENT CHALLENGE

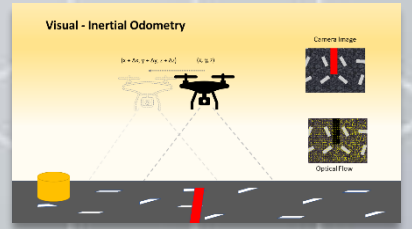




MathWorks Excellence in Innovation Robotics Projects







View the 2022 Simulink Student Challenge winners

Examples

University of Stuttgart

Goal

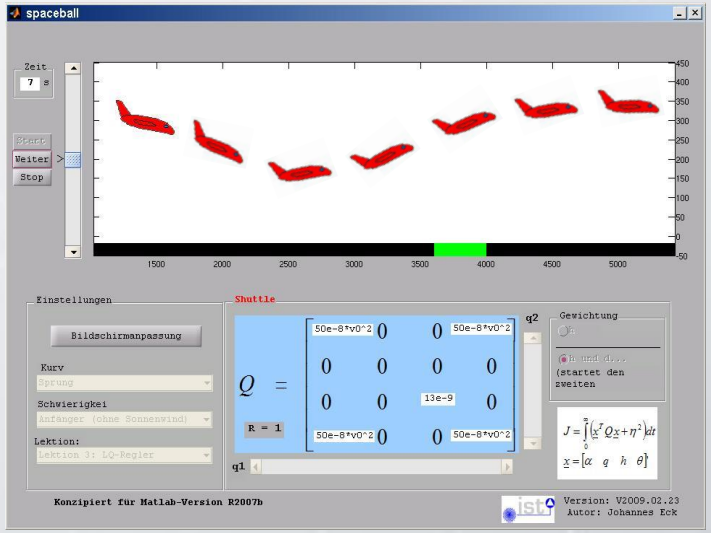
Excite students in Automatic Controls course; help them connect theory to real-world engineering

Approach

Customized MATLAB and Simulink to create *SpacecraftRT*, an educational game

Outcomes

- Hands-on interactivity rapidly engages students; provides context for theory
- Provides easy link between using GUI for What-if exploration followed by learning MATLAB and Simulink



"Games allow students to apply complex methods to realistic, yet simple, control problems.

It is a small step from GUI-based controller design to MATLAB coding."

Prof. Frank Allgöwer
Institute for Systems Theory and Automatic Control

"A MATLAB-Based Game for Advanced Automatic Control Education" 8th IFAC Symposium on Advances in Control Education, Kumamoto, Japan, 2009. U. Münz, C. Böhm, J. Eck, M. Reble, P. Schumm & F. Allgöwer.

Penn State GATE Program

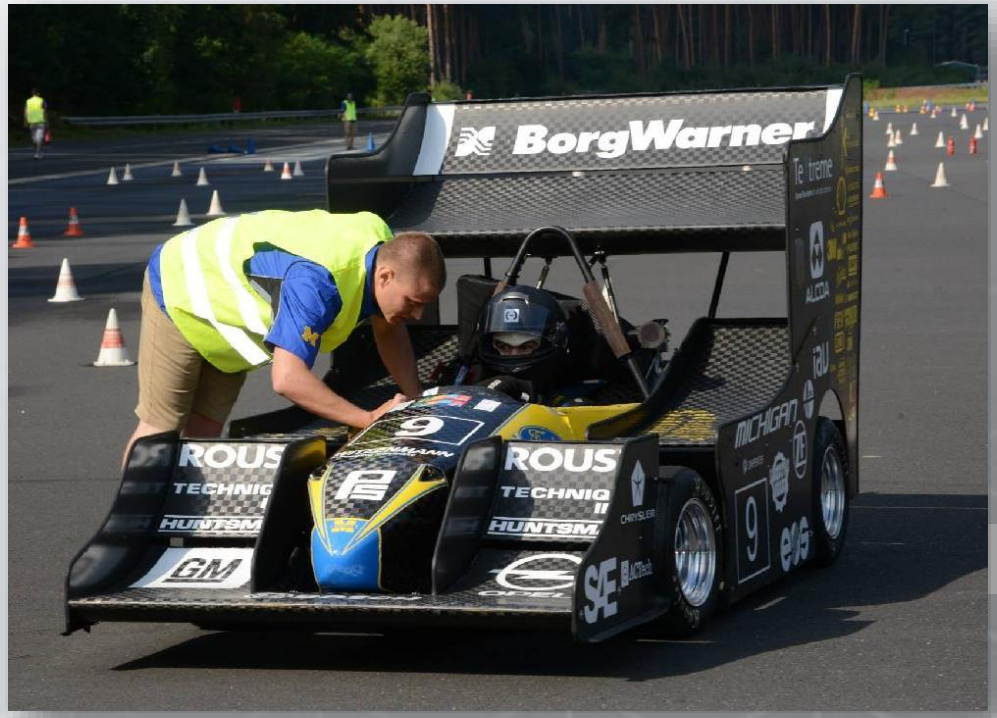
- Teach the full development process
- Utilize a single platform for design, verification, hardware-in-the-loop testing, and final implementation
- Speed up student learning by introducing more concepts in the classroom and providing hands-on learning opportunities
- Equip students to “hit the ground running” when entering industry

“I was recruited to work at General Motors before I even finished graduate school. And I think that one of the things that made me attractive was my hands-on experience with tools like MATLAB and Simulink…”

Melanie Fox, PhD Candidate
Diesel Combustion Engineer, GM

Student Experience: Transitioning to Industry

"This high-level, abstract understanding of complex systems is a skill set that is highly sought after in the automotive industry these days." ***Joe Martin, former University of Michigan student***

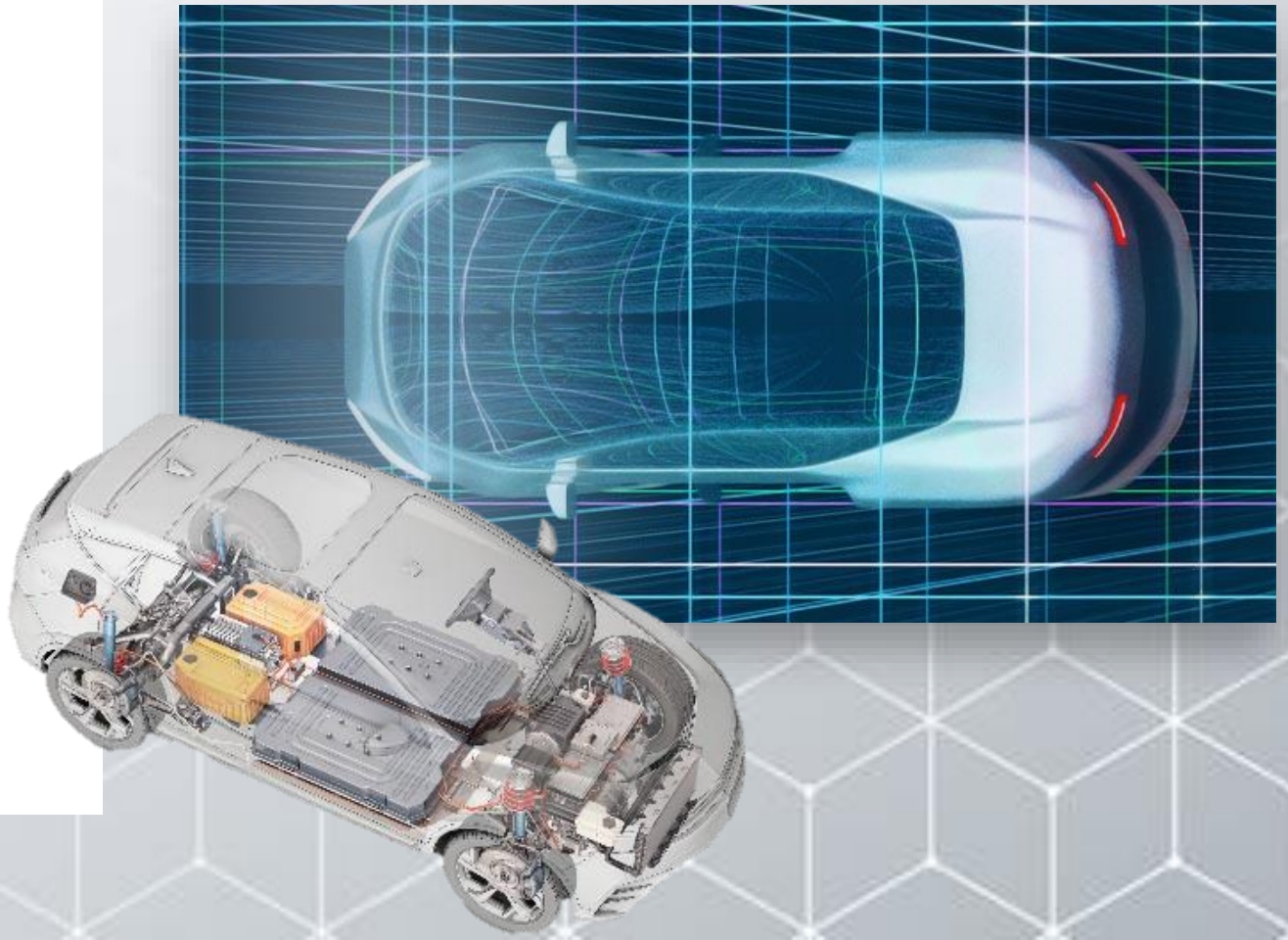


"They were confident that I had the knowledge to excel in the position because the tasks I completed in EcoCAR were almost the same tasks that full-time controls engineers do." ***Jessica Britt, former Georgia Institute of Technology student***

Bosch and National Institute of Technology Calicut Collaborate on EV Course to Prepare Students for Industry

"The collaboration between NIT Calicut, MathWorks, and Bosch narrowed the gap between academia and industry, producing an electric vehicle system engineering course that has been both well received by our students and highly useful for them as well."

— *Dr. Kumaravel Sundaramoorthy, NIT Calicut*



Project-Based Learning and Design with Simulation

Professor Claire Lucas, King's College London

1.00

Benefits

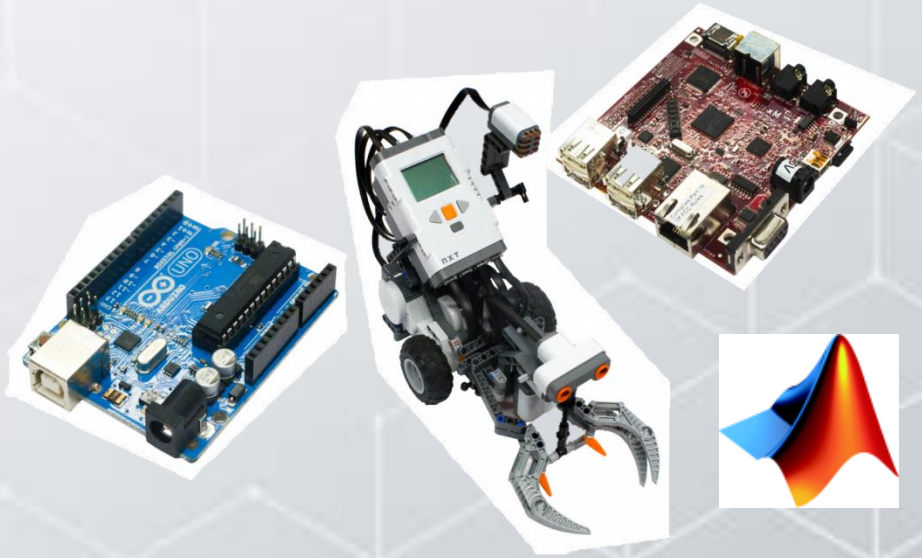
Simulation and Learning

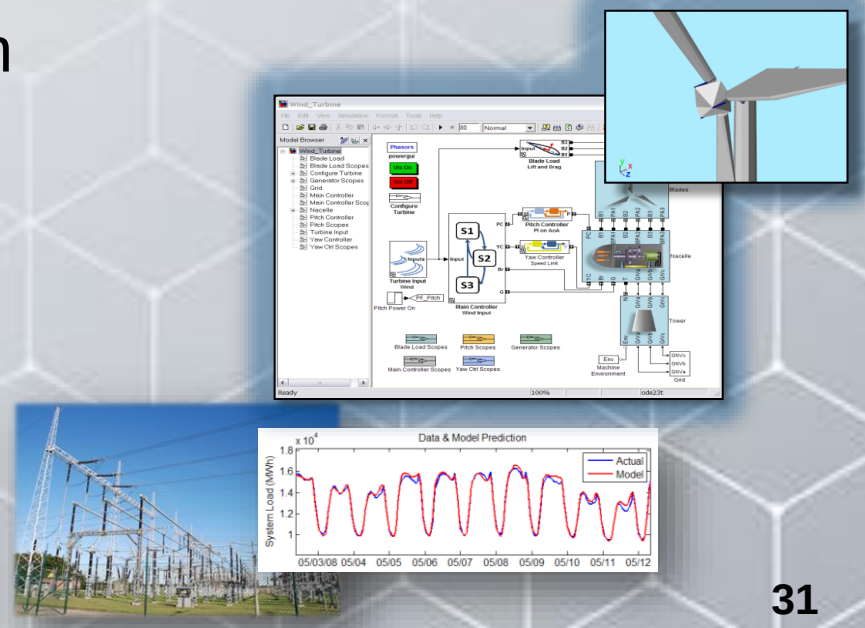
- Combining mathematical and physical modelling gives **multiple perspectives** on systems
- Simulation is an integral part of the **design process** – modelling beyond understanding
- This is a key enabler for developing **systems thinking skills** – students learn how components behave when integrated together
- Bespoke **individual assessment environment** builds confidence in simulation software and is then utilised as a virtual test environment by students
- **Hardware in the loop** and deployment onto Arduino allows students to move between simulation and hardware in end-to-end workflow

Summary

Summary

- Project-Based Learning – Learning by Doing
- Multi-Domain projects
  - Simulation and hardware solutions
  - Multi-Domain integration
  - Industry-driven workflow for engineering education





Thanks for listening!

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