/in/melda-ulusoy/

/in/jennifer-gago/

MATLAB EXPO

Teaching Robotics & Controls Made Easier

Melda Ulusoy, MathWorks

(She/They)

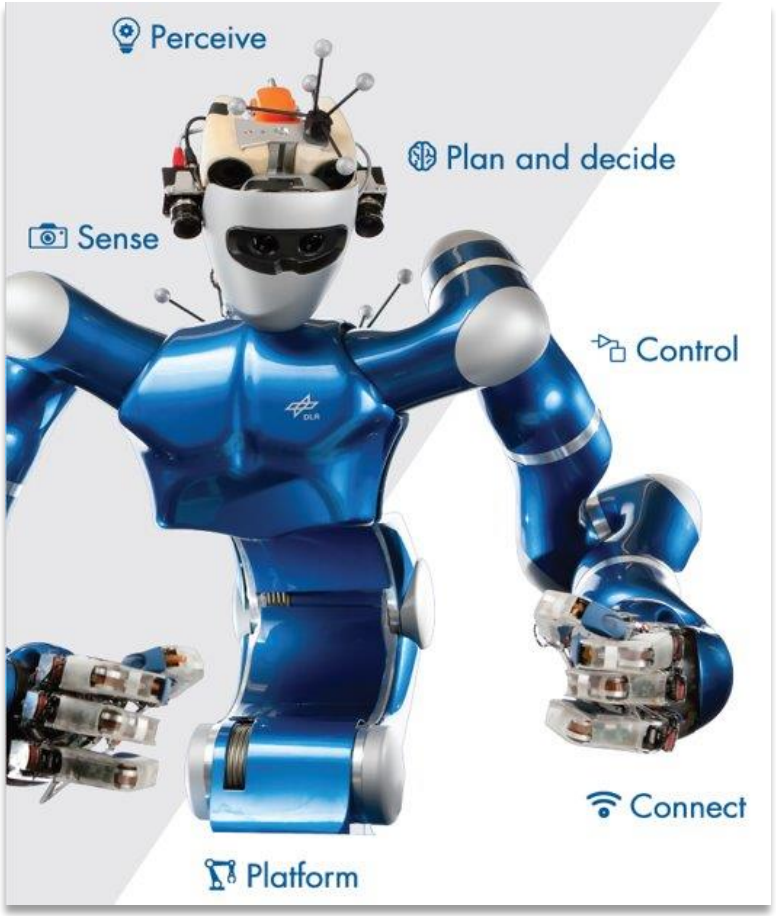
Jennifer Gago, MathWorks

(She/They)

MathWorks

Design Robotic Systems with MATLAB & Simulink

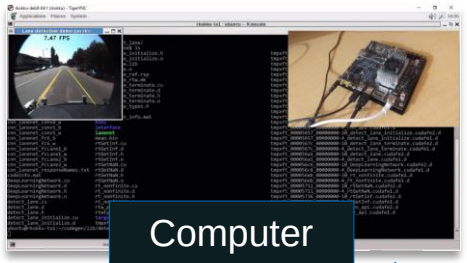
German Aerospace Centre use Model-Based Design with MATLAB & Simulink



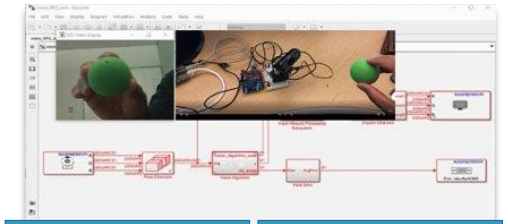
*"**Model-Based Design** with MATLAB and Simulink covers a wide range of software domains needed for the **design of advanced robotic systems**. It enables the **simulation** of complex mechatronic systems and **controllers**, **code generation** for real-time HIL testing, **signal and image processing**, and **data analysis and visualization**."*

Berthold Bäuml
Director, Autonomous Learning Robot Lab,
German Aerospace Centre

Teach Robotic Systems Design with MATLAB & Simulink

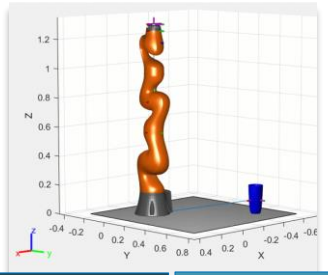


Computer vision



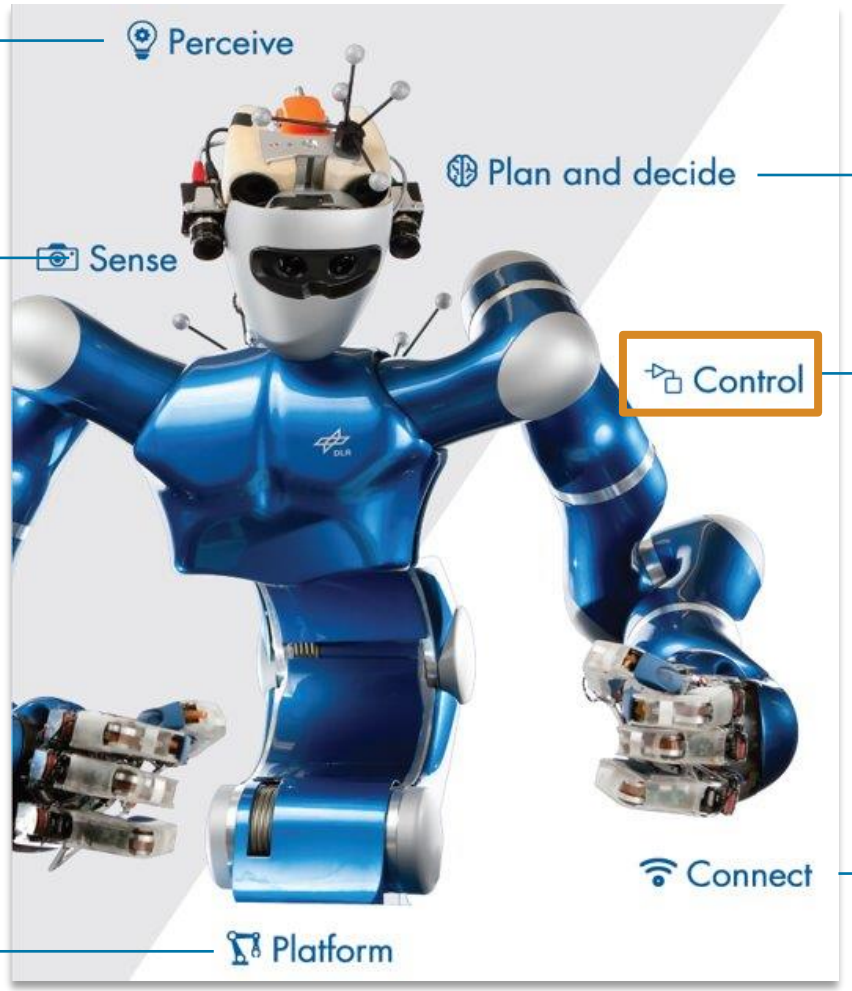
Electronic instrument.

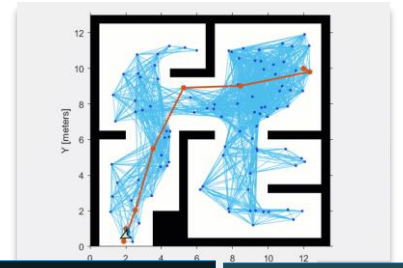
Sensors & actuators



Industrial robots

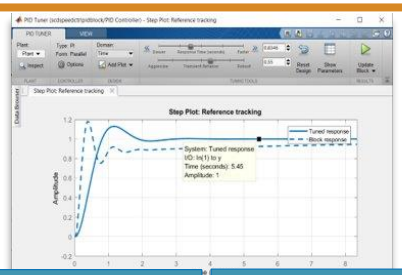
Mechanical engineering





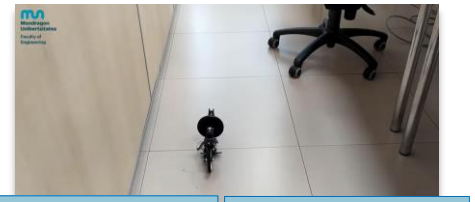
Intelligent decision

Mobile robots



Control engineering I

Control engineering II



Telemmatic syst. design

Communic. protocols

Challenges that instructors face today

in teaching robotics and controls courses

How to..

1. Develop a curriculum under **time constraints**?
2. Gauge **student interest** during class?
3. Facilitate **independent learning**?
4. Scale access to resources for **hands-on learning**?
5. **Grade student assignments** at scale?
6. **Challenge students** with innovative engineering topics?

Address the teaching challenges

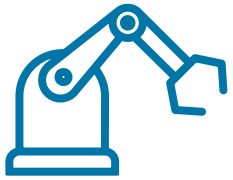
Today's agenda

1 Preparation

2 Lessons

3 Study

4 Laboratories



5 Evaluation

6 Student Programs

Leverage ready-to-use courseware

Save time during course preparation

Preparation

Lessons

Study

Laboratories

Evaluation

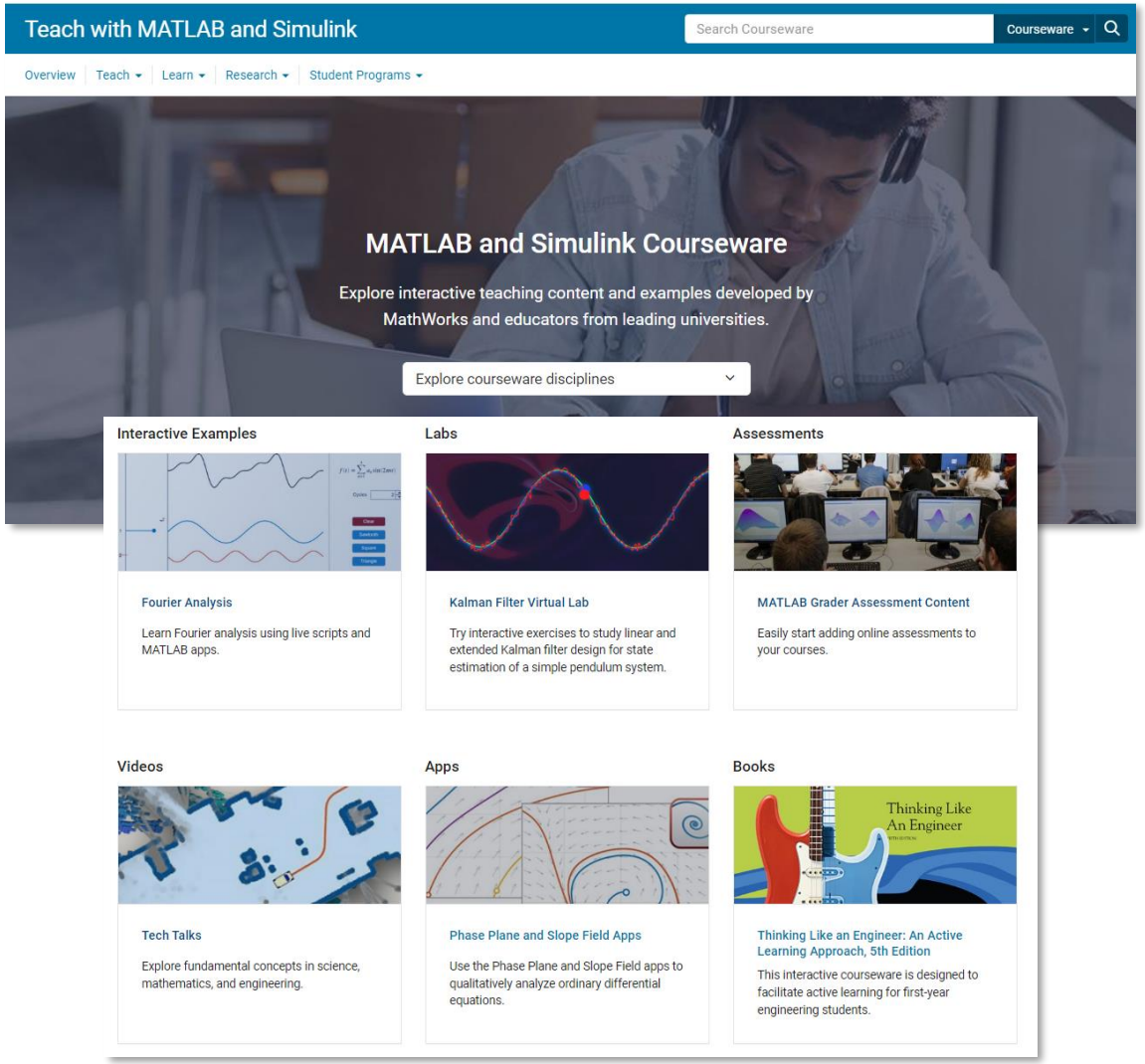
Student Programs

Explore interactive teaching content

Controls and robotics courseware

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

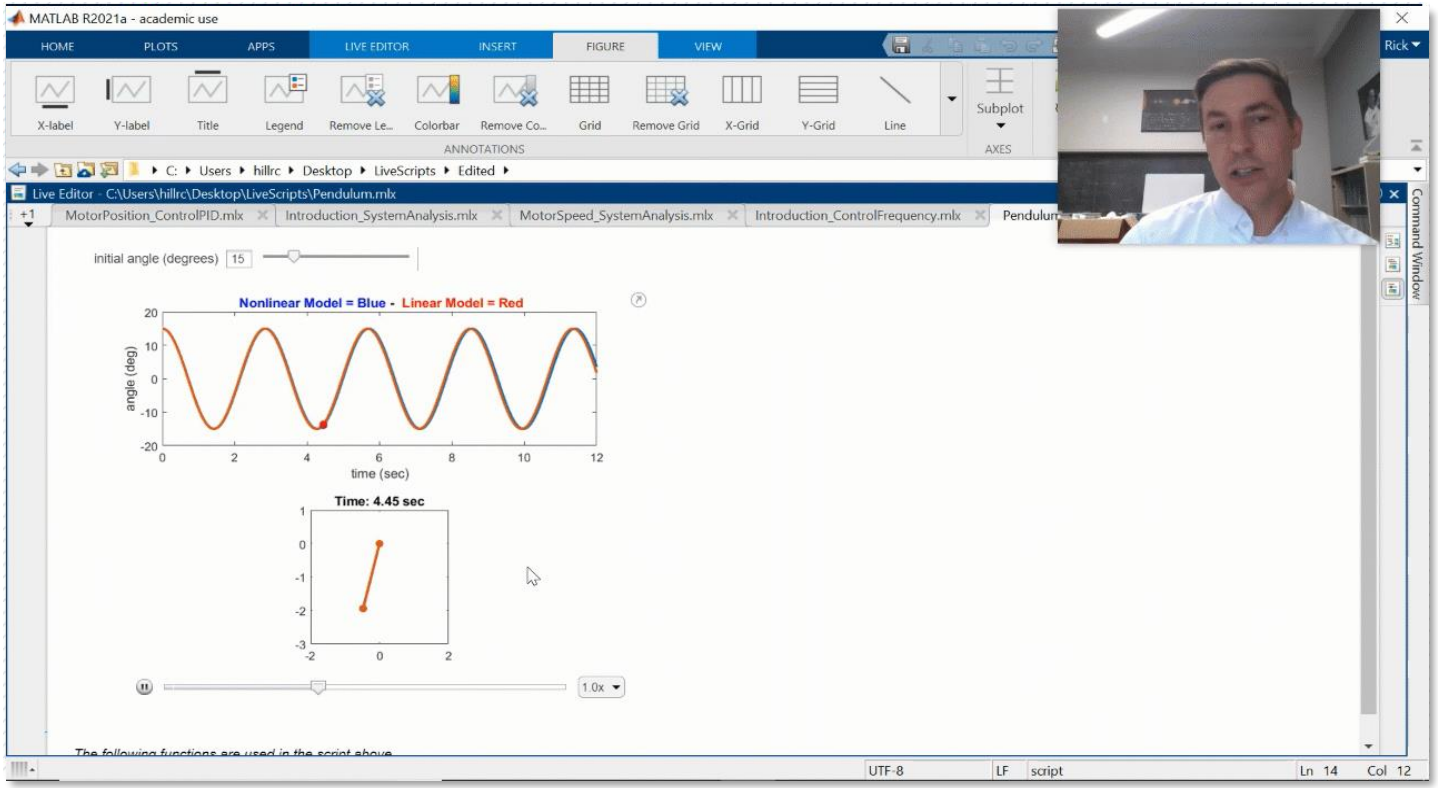
- Awesome Robotics with MATLAB & Simulink
- Control Tutorials with MATLAB & Simulink
- Robotics Playground
- Applied Autonomous Robots I
- Applied Autonomous Robots II
- Mobile Robots Control
- Reinforcement Learning with MATLAB
- Electromechanical Engineering Systems
- MATLAB and Simulink ROS Tutorials



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



Engage your students in practical and dynamic lessons

Use interactive tools

Preparation

Lessons

Study

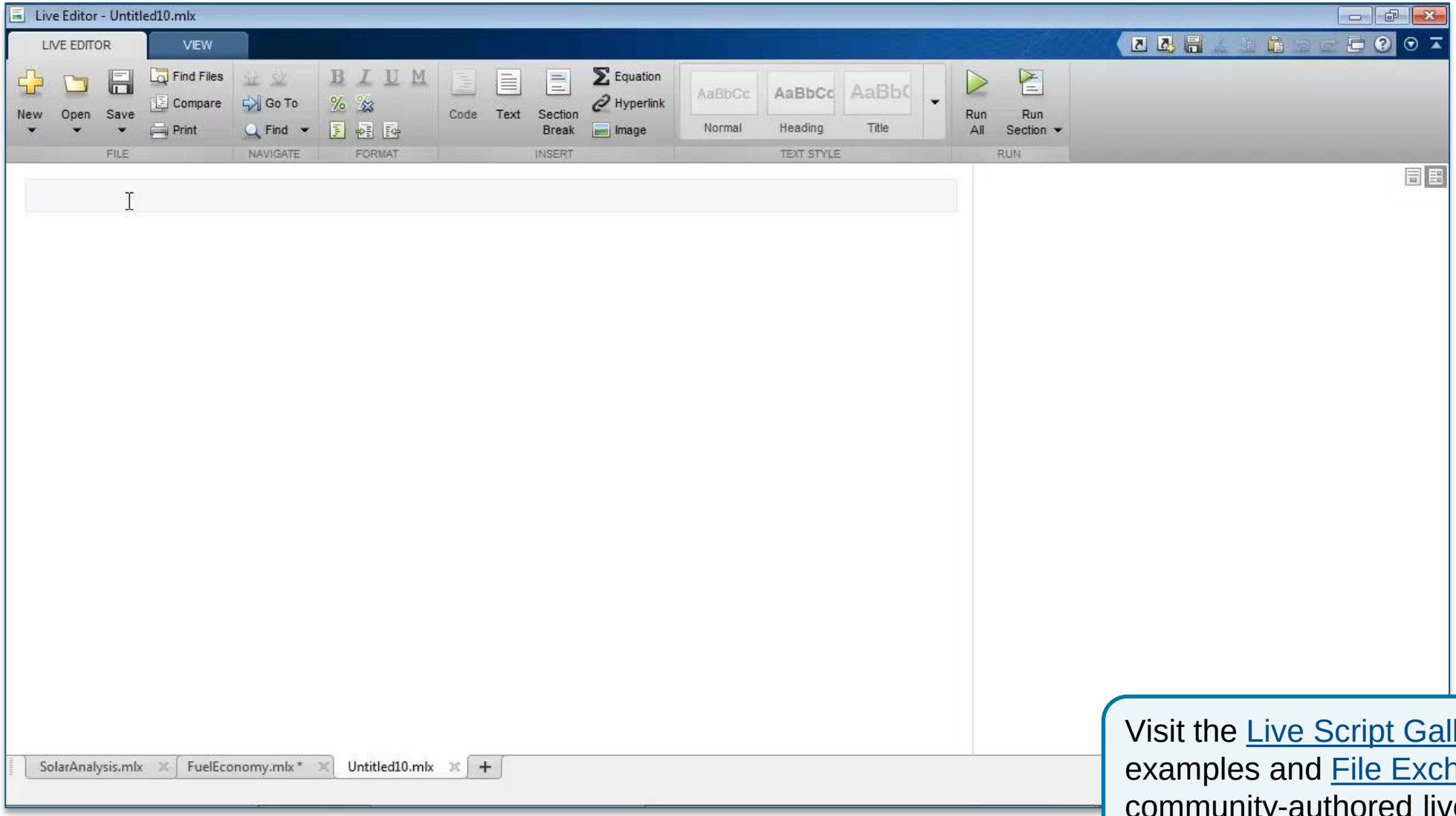
Laboratories

Evaluation

Student programs

Teach with Interactive Scripts

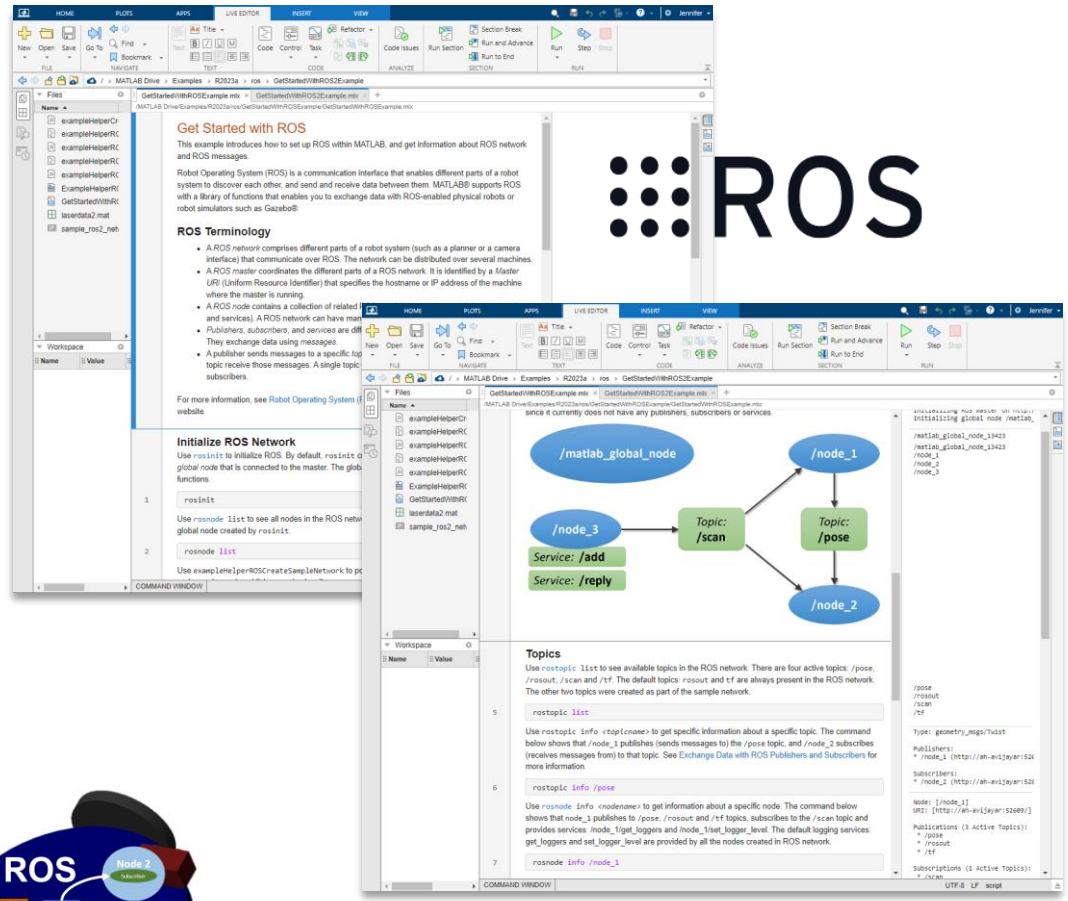
Live Scripts combine text, images, equations, links, code and results



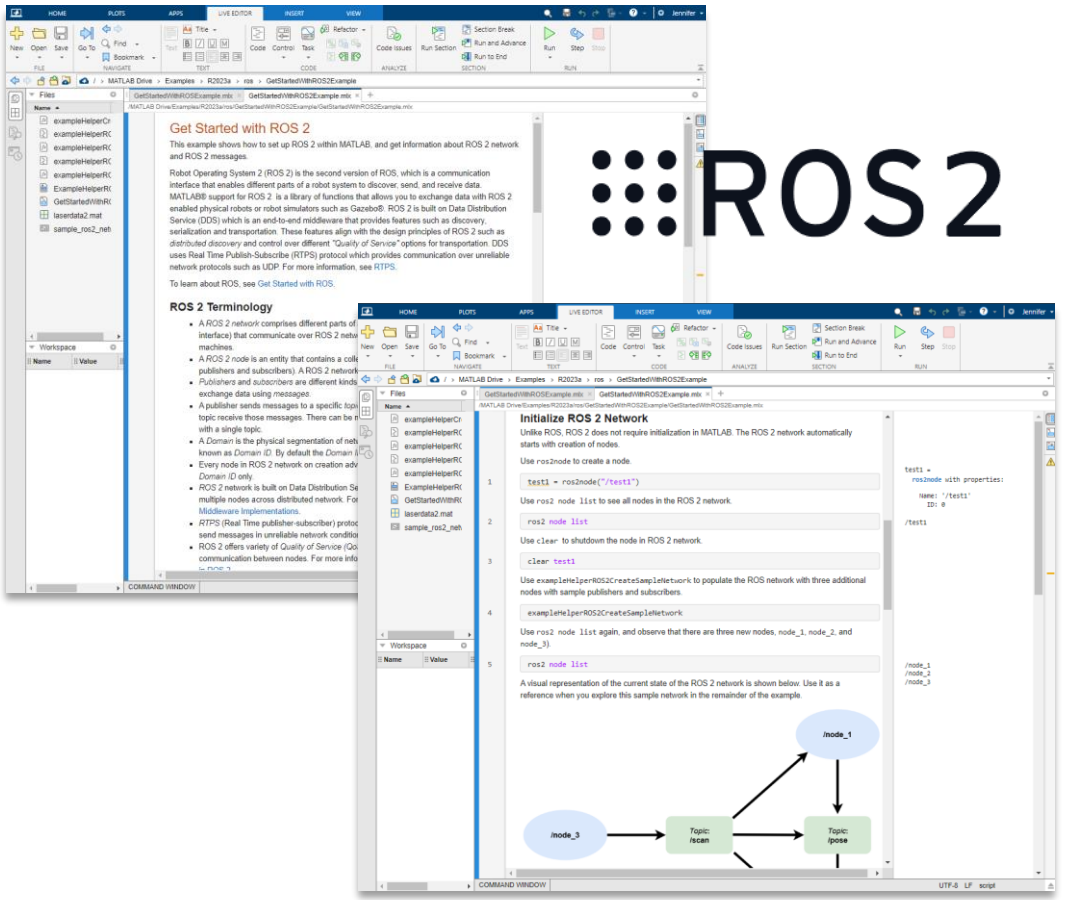
Visit the Live Script Gallery for examples and File Exchange for community-authored live scripts

Get started with ROS and ROS2

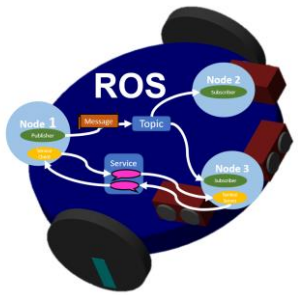
Open and run Live Script documentation and tutorials



ROS



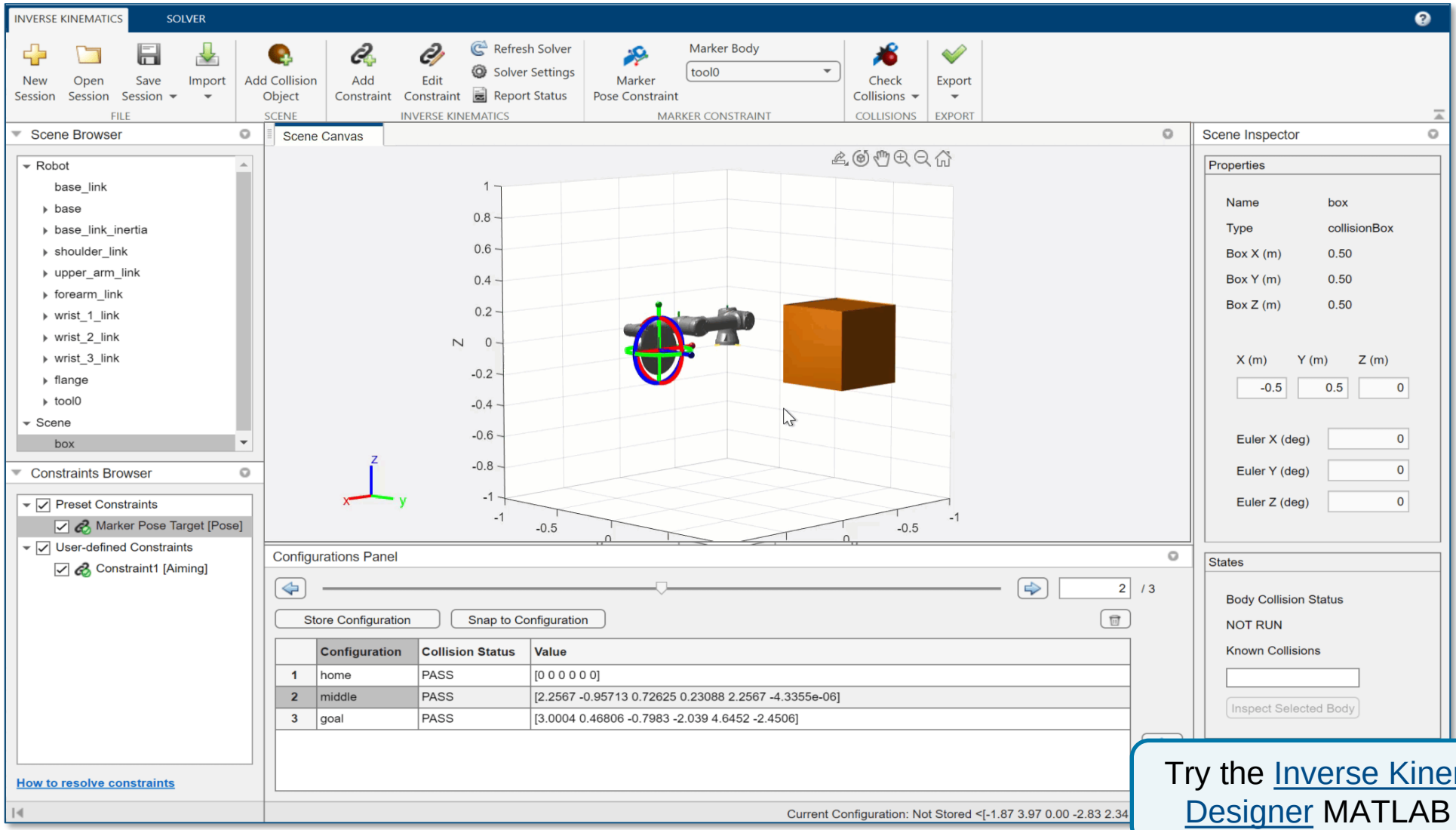
ROS2



[MATLAB and Simulink ROS Tutorials]

Teach theoretical concepts through interactive apps

This MATLAB App solves the inverse kinematics of a URDF robot model

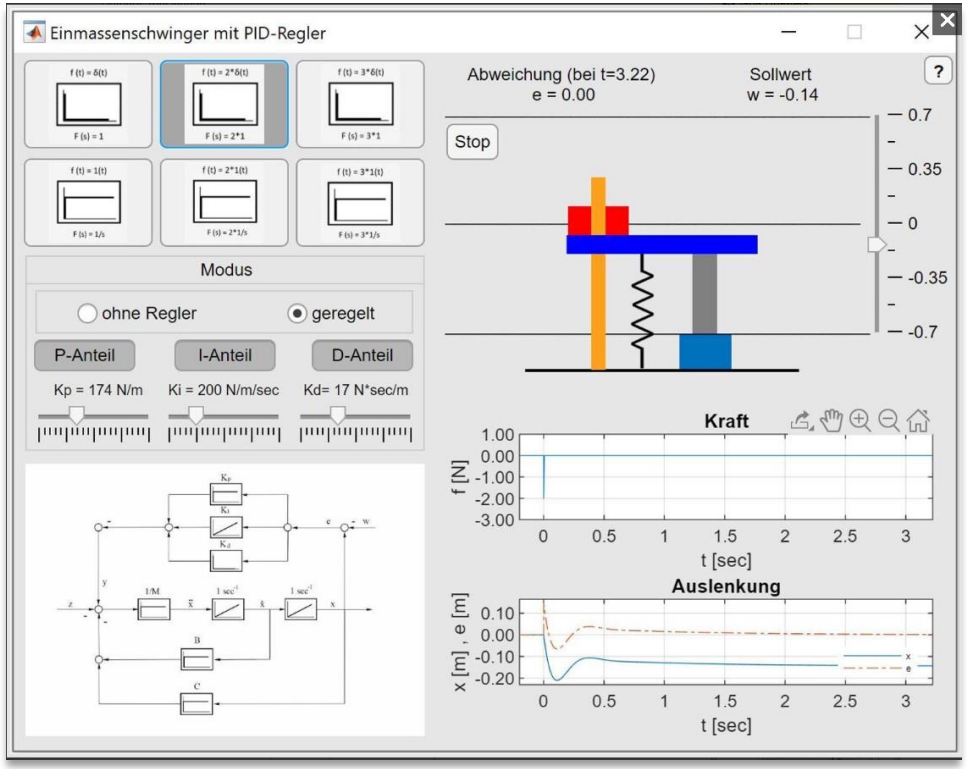


Try the Inverse Kinematics Designer MATLAB App!

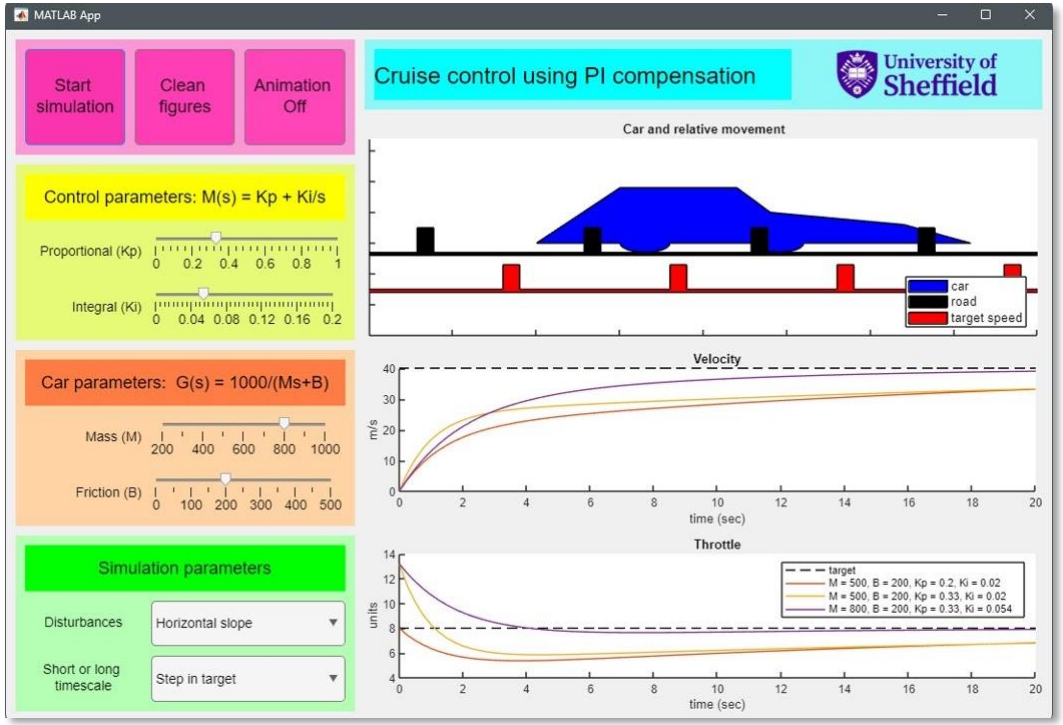
Reuse apps developed by universities

Control apps created with MATLAB App Designer

Controls apps by RWTH Aachen University allow students to study **control design and frequency response analysis** using Bode and Nyquist plots on mass-damper and inverted pendulum systems



Controls apps by University of Sheffield allow students to study **dynamic system behavior** and **PI control design** using mixing tank and cruise control examples

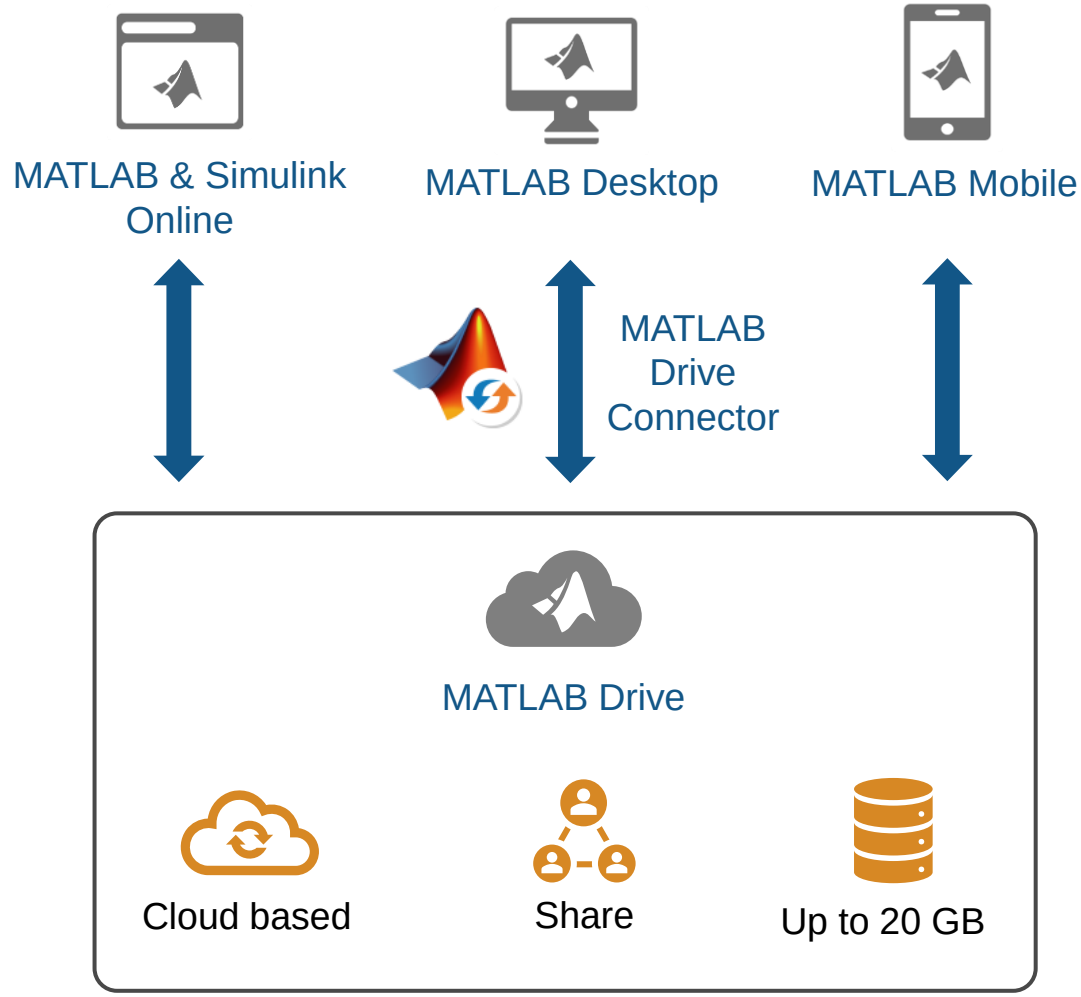


Access tools and files everywhere

MATLAB & Simulink in the cloud

- Run MATLAB and Simulink in your **browser** with MATLAB Online and Simulink Online
- Run MATLAB in your **mobile devices** with MATLAB Mobile
- Collaborate and provide **cloud storage** for sharing course material using MATLAB Drive or GitHub

Explore MathWorks cloud resources



Facilitate independent learning for students

Complement in-class instruction with self-paced trainings and educational videos

Preparation

Lessons

Study

Laboratories

Evaluation

Student programs

Get started with MATLAB & Simulink for robotics and controls

Free self-paced online courses

MATLAB Onramp

14 modules | 2 hours | Languages

Get started quickly with the basics of MATLAB.

Simulink Onramp

14 modules | 2 hours | Languages

Get started quickly with the basics of Simulink.

Control Design Onramp with Simulink

7 modules | 1 hour | Languages

Get started quickly with the basics of feedback control design in Simulink.

Reinforcement Learning Onramp

5 modules | 3 hours | Languages

Master the basics of creating intelligent controllers that learn from experience.

Machine Learning Onramp

6 modules | 2 hours | Languages

Learn the basics of practical machine learning methods for classification problems.

Deep Learning Onramp

5 modules | 2 hours | Languages

Get started quickly using deep learning methods to perform image recognition.

Computer Vision Onramp

6 modules | 2 hours | Languages

Learn the basics of computer vision to design an object detector and tracker.

Image Processing Onramp

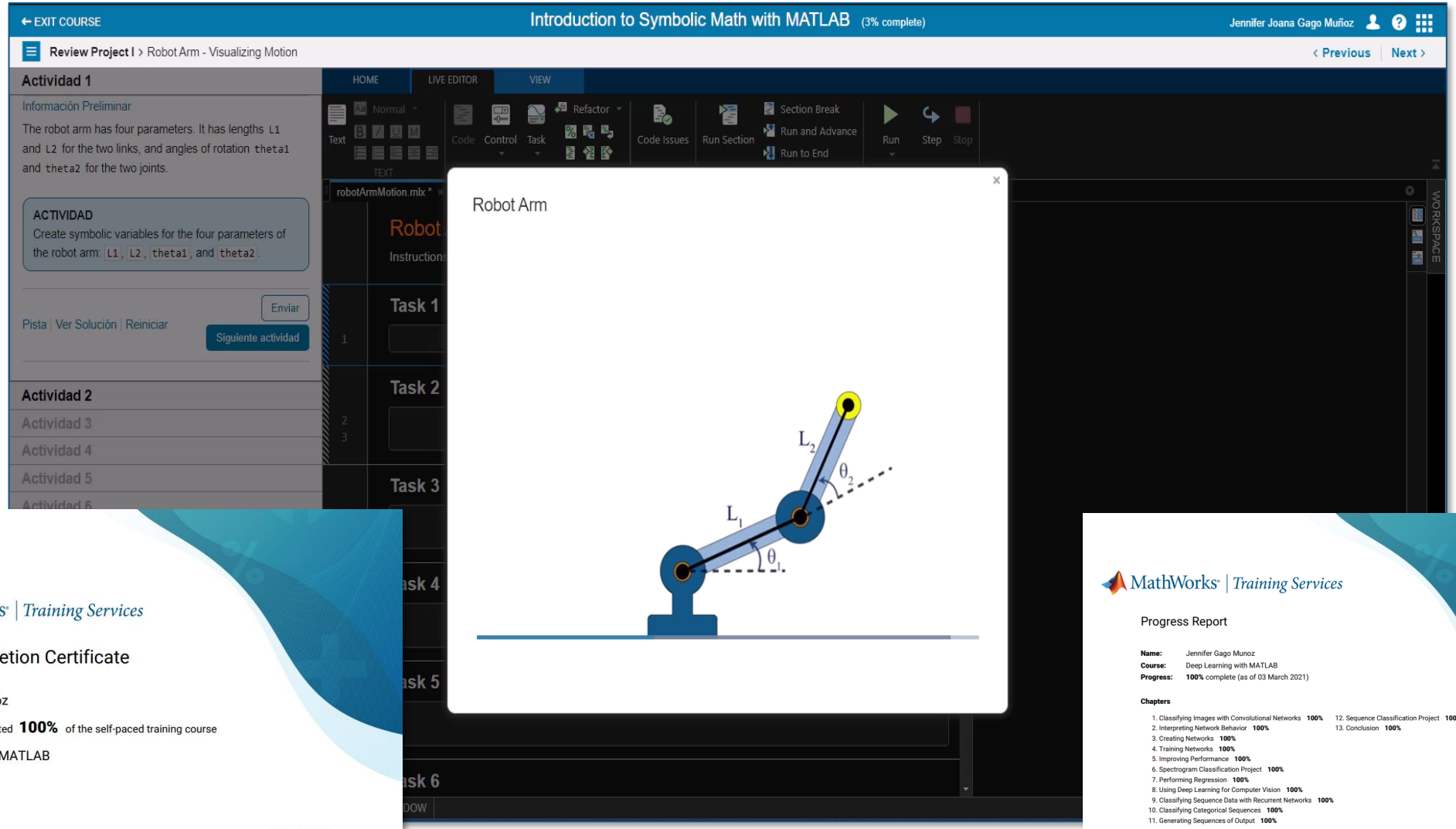
6 modules | 2 hours | Languages

Learn the basics of practical image processing techniques in MATLAB.

Visit the self-paced courses page!

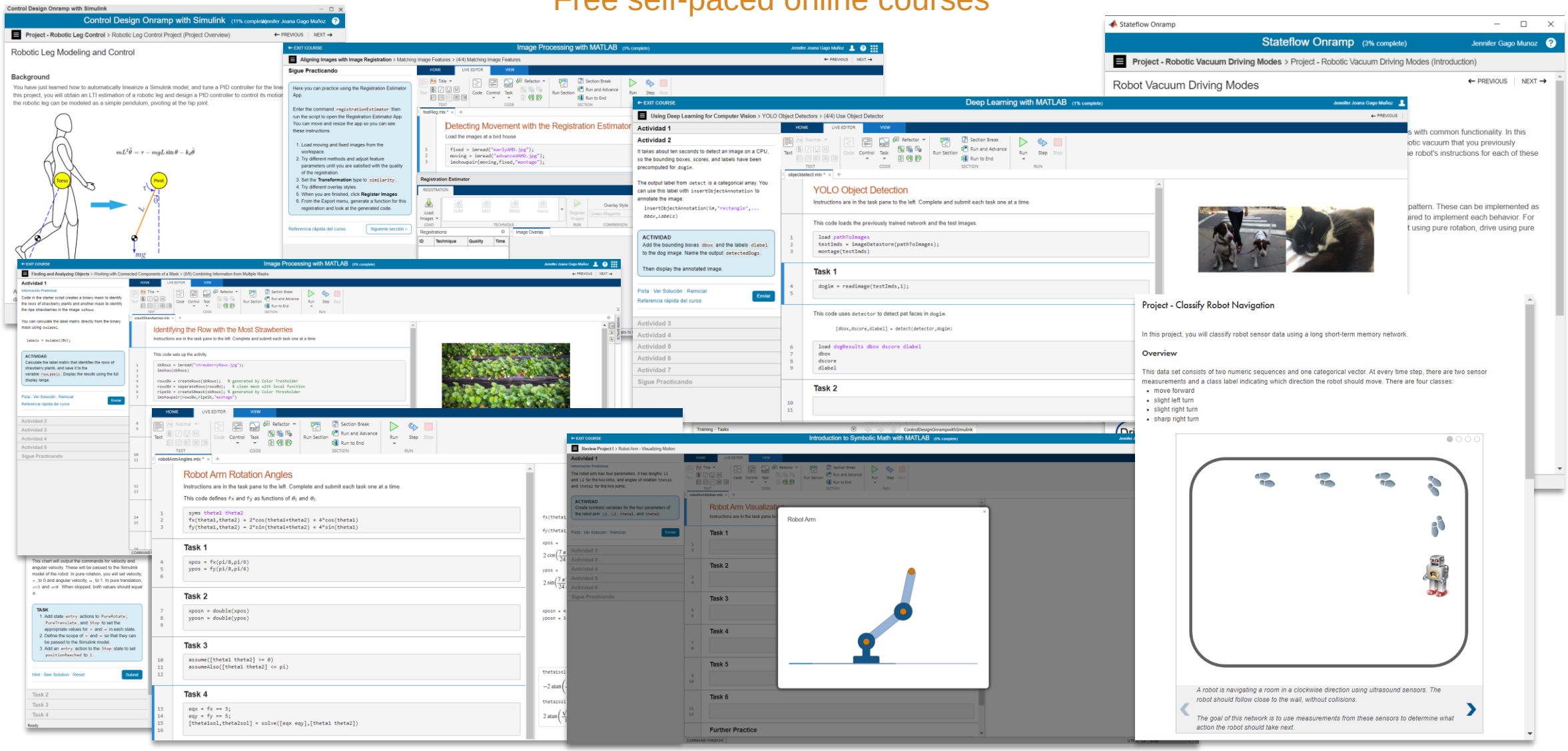
Solve practical exercises and complete projects

Free self-paced online courses



Find relevant robotics and controls examples

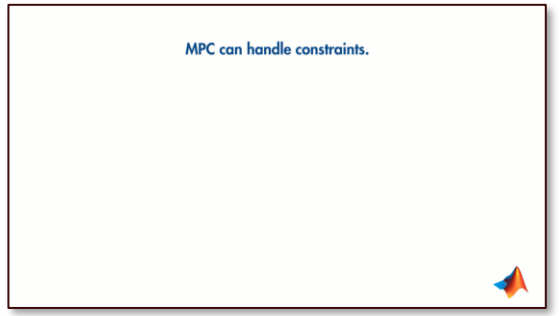
Free self-paced online courses

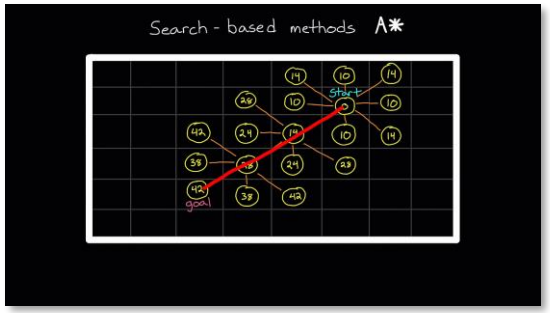


Supplement your teaching of engineering concepts

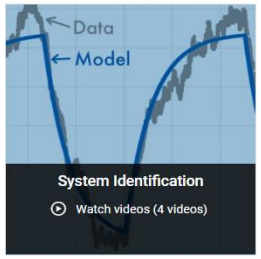
MATLAB Tech Talks: Educational videos for students

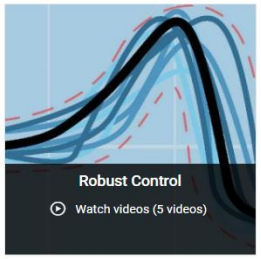
- Tech talks help students gain intuition into complex engineering concepts with **easy-to-understand examples**

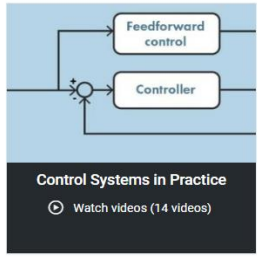


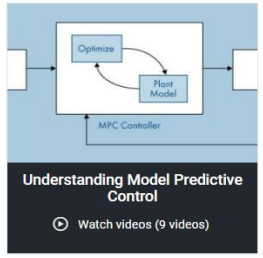


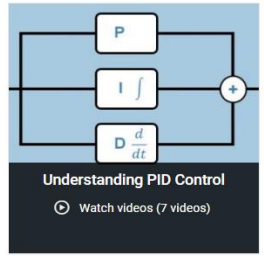
- Visit the MATLAB YouTube channel and Control Systems Tech Talk Library for existing and new videos!

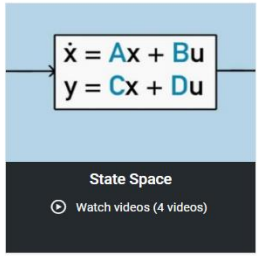


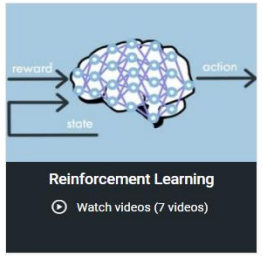


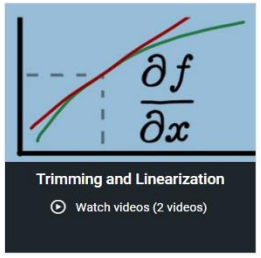


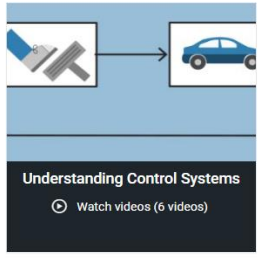


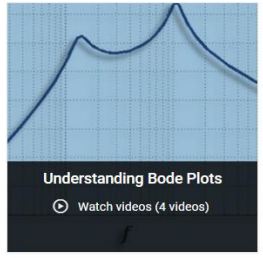


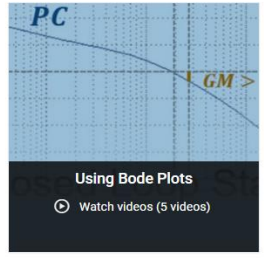


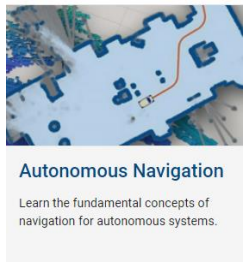












Scale access to resources for hands-on learning

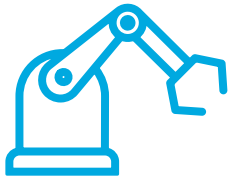
Build virtual and low-cost hardware labs

Preparation

Lessons

Study

Laboratories

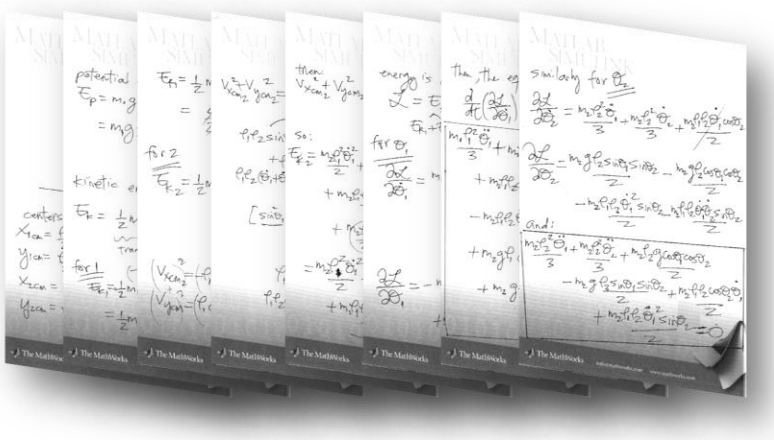


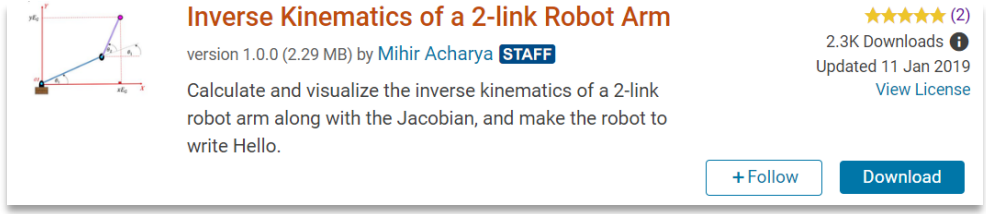
Evaluation

Student Programs

Build a virtual lab from written notes

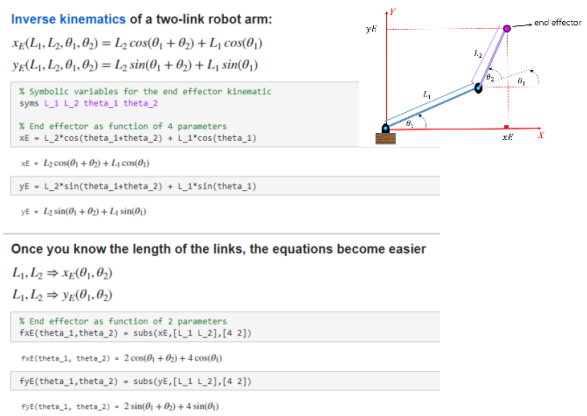
MATLAB, Simulink and Simscape help you design practical applications based on core concepts



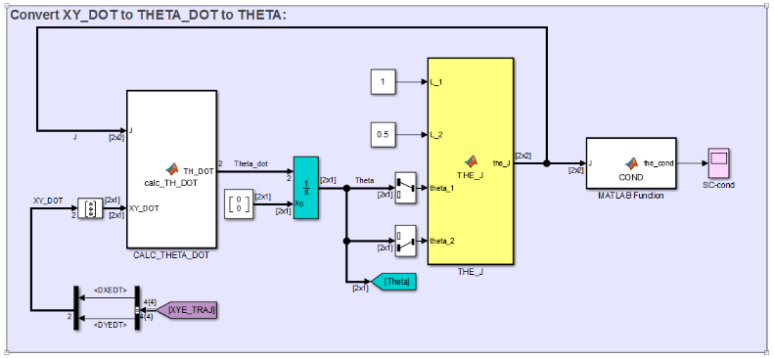


Download this example from File Exchange!

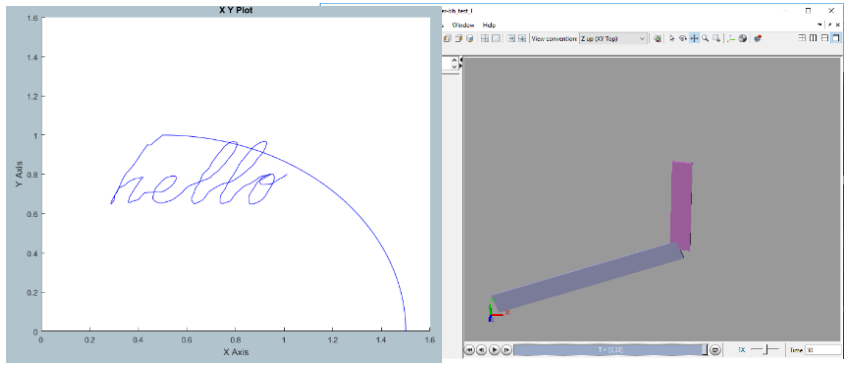
MATLAB



Simulink



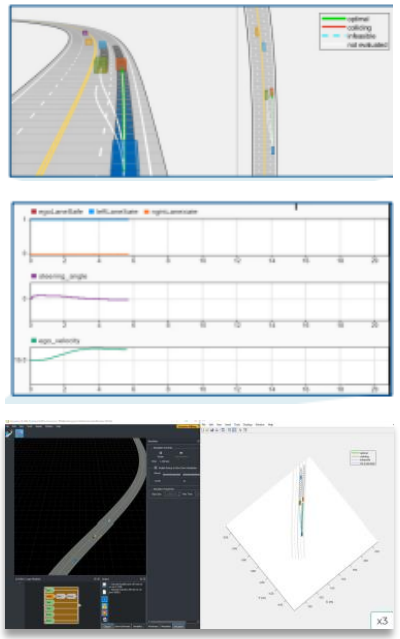
Simscape



Simulate multiple virtual environments

Virtual labs using Simulink with additional tools

Automated driving

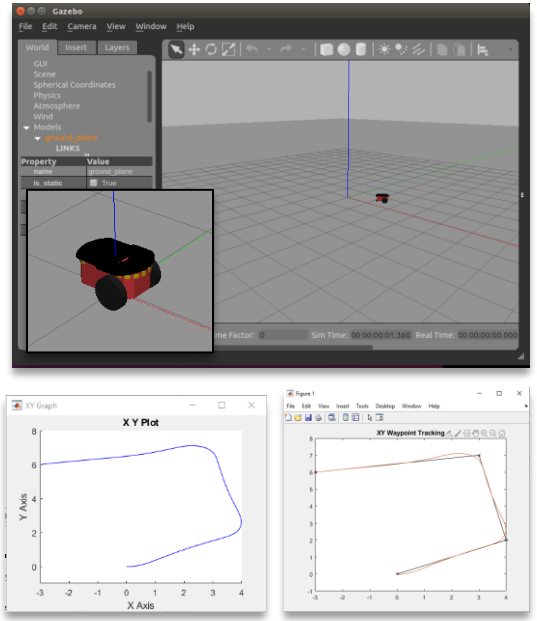


[RoadRunner]

VR environments

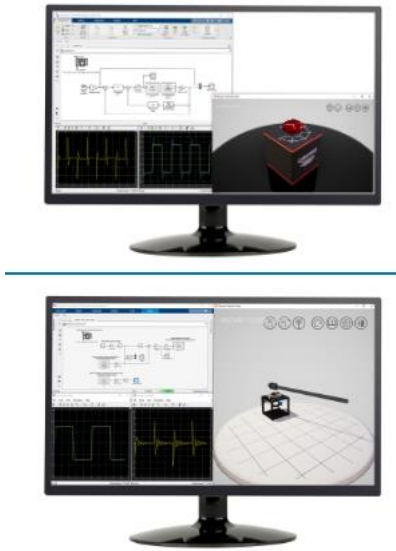
[Simulink 3D Animation]

Co-Simulation



[Gazebo]

Digital twins

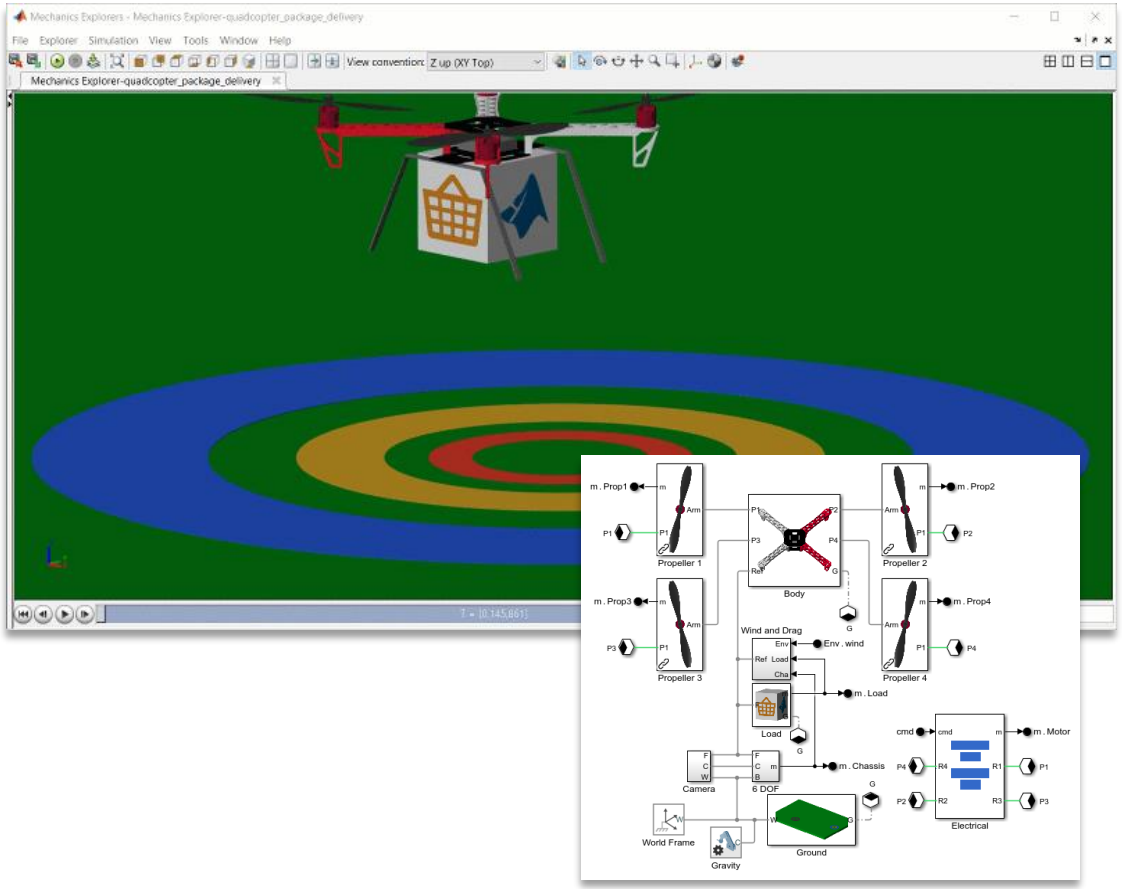


[Quanser Labs]

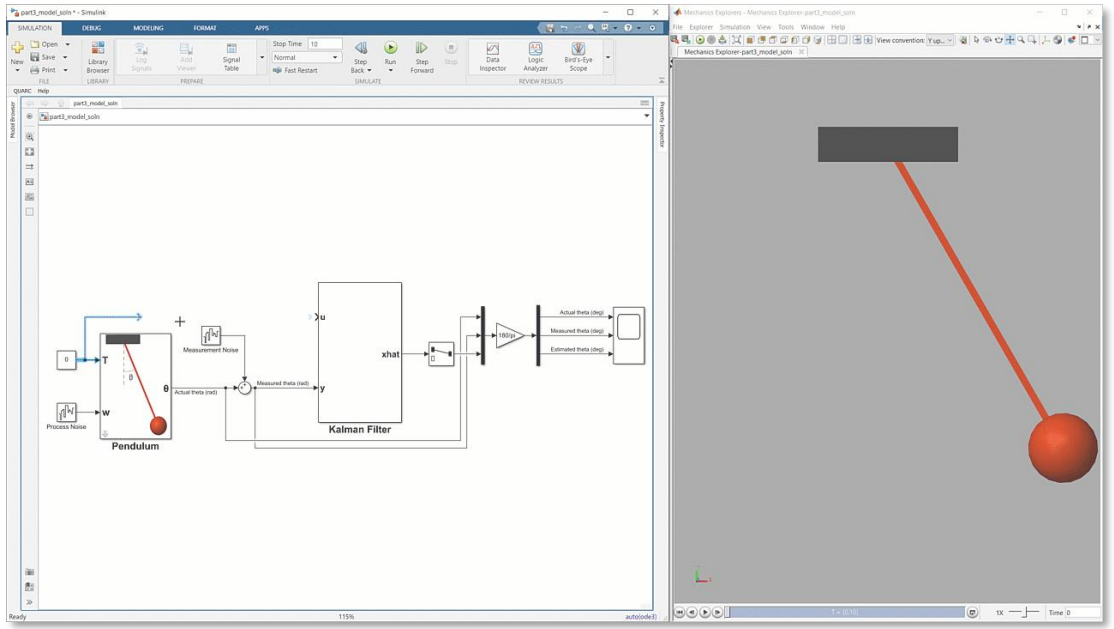
Use virtual labs based on physical models

Simscape-based labs by MathWorks

This Delivery Quadcopter example shows how to model the control, mechanical and electrical systems of a UAV.



Kalman Filter Virtual Lab contains interactive exercises for students to study linear and extended Kalman filter design

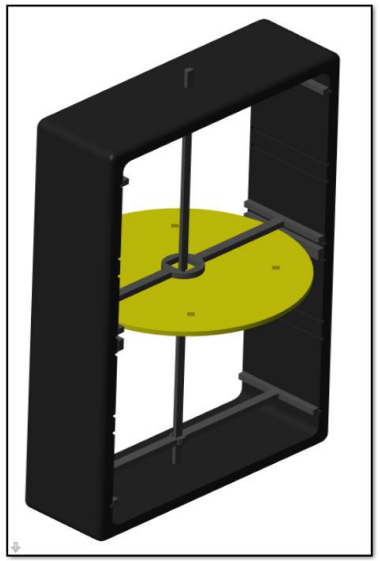


*Solutions available upon instructor request.
Contact us at onlineteaching@mathworks.com

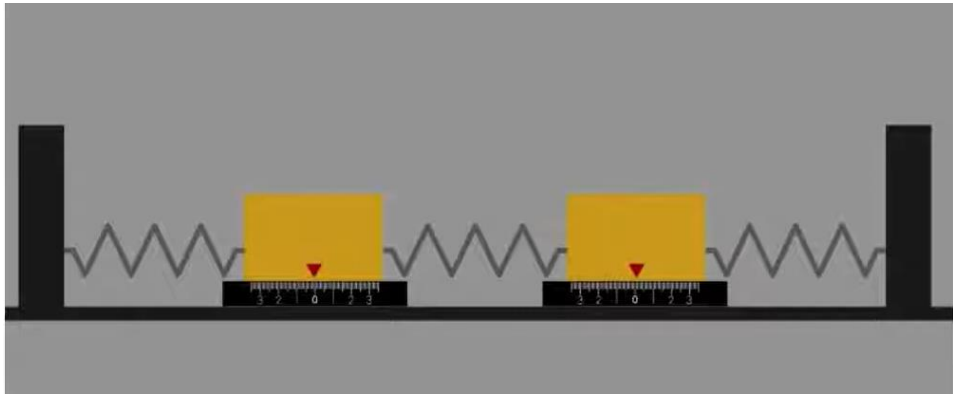
Reuse virtual labs developed by universities

Simscape-based labs by Kennesaw State University

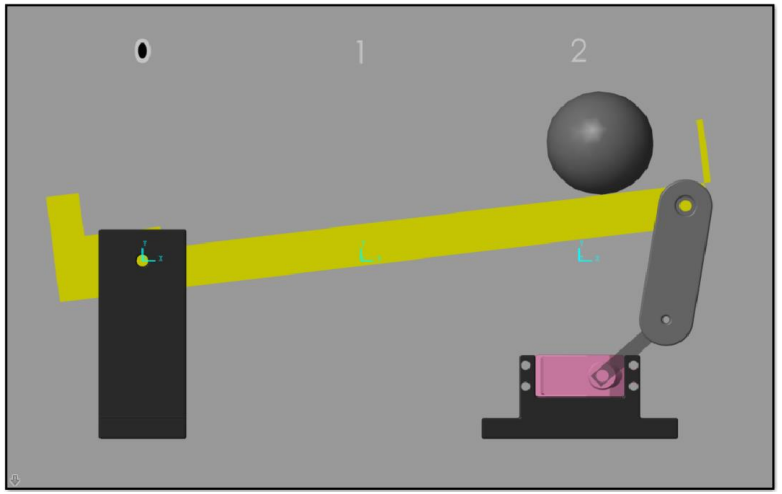
- Vibration and control virtual labs provide various virtual mechanisms that students can use to study topics such as free and forced response of multi dof systems, mode ratios and pid control
- Download vibration and control virtual labs and supporting curriculum materials



PID Controlled disc



Mass-spring system

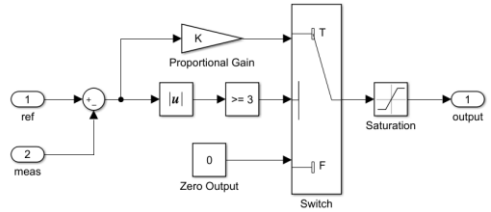


PID Ball control

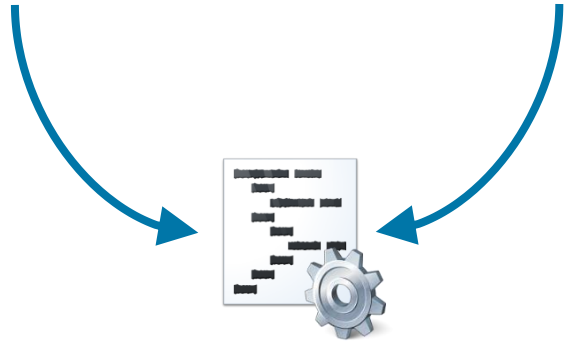
Connect MATLAB & Simulink to hardware

Hardware Support

```
if inp >= 1
    out = K*inp;
elseif inp < 0
    out = 0;
else
    out = 1;
end
```



MATLAB **Simulink**



Automated code generation
Coder/Embedded Coder (C/C++),
HDL Coder, PLC Coder, GPU Coder

Check our hardware support page!

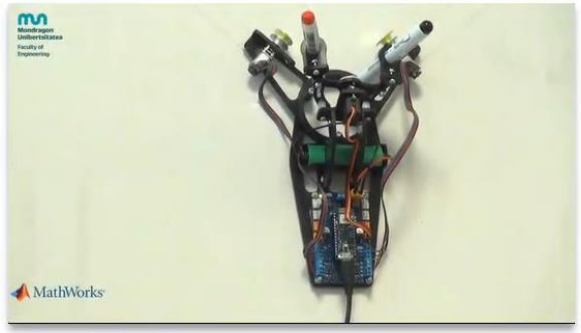
Use low-cost hardware for project-based learning

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

Self-balancing motorcycle

Drawing robot



Autonomous rover

File Exchange

MATLAB Central | Files | Authors | My File Exchange | Publish | About

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!

Assess learning at scale and get immediate feedback

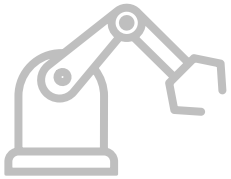
Auto-grade assignments

Preparation

Lessons

Study

Laboratories



Evaluation

Student Programs

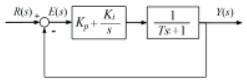
Auto-grade student work with MATLAB Grader

System Dynamics and Controls Problem Collection

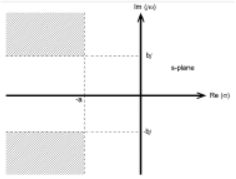
LAB SESSION 1 – CONTROL ENGINEERING I

PI CONTROLLER DESIGN WITH MATLAB

In this problem, you will write a function that designs and returns a PI controller for the system illustrated below:



It is desired that the closed-loop poles have a real part less than -a and an imaginary part greater than b (or less than -b). Your function should accept the two parameters, a and b, as input, along with the first-order plant time constant, T. Modify the solution template by adding formulas to compute the proportional and integral control gains, Kp and Ki, from so that the poles of the closed-loop system lie in the shaded region of the complex s-plane shown below:

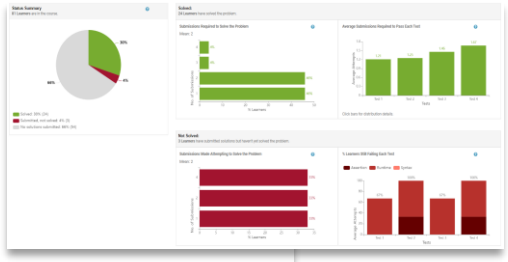


The function declaration is given below.

```
function [Kp,Ki,wn] = PIcontrol(a,b,T)
Kp = ;
Ki = ;
end
```

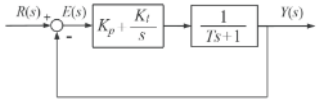
Code is also provided to test your function:

```
a = 5;
b = 7;
```

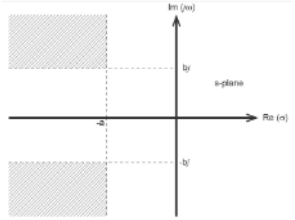


Design a PI Controller

In this problem you will write a function that designs and returns a PI controller for the system illustrated below:



It is desired that the closed-loop poles have real part less than -a and imaginary part greater than b (or less than -b). Your function should accept the two parameters, a and b, as input, along with time constant of the first order plant, T. Modify the solution template by adding formulas to calculate the proportional and integral control gains, Kp and Ki, such that the poles of the closed-loop system are placed in the shaded region of the complex s-plane shown below:



The function declaration has been provided for you in the solution template. Code has also been provided to test your function in the 'Code to call your function' box.

Function Reference Solution | Save | Reset | MATLAB Documentation

```
function [Kp,Ki,wn] = PIcontrol(a,b,T)


Kp = ;

Ki = ;

end
```

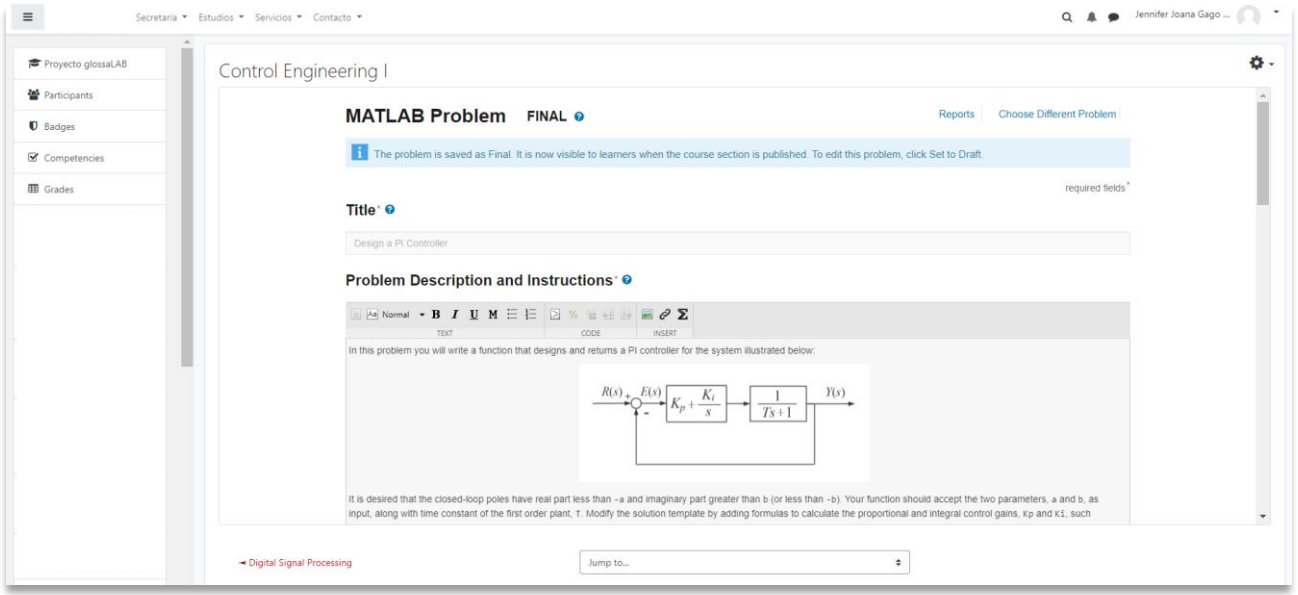
Code to call your function Reset

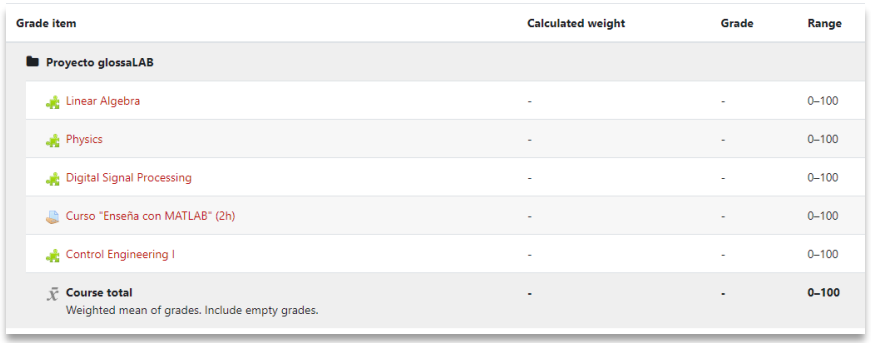
```
a = 5;
b = 7;
T = 1;
[Kp,Ki,wn] = PIcontrol(a,b,T)
```

Use MATLAB Grader and explore the problem collection!

Integrate MATLAB Grader with your LMS

Interactive homework on Moodle, Blackboard, Canvas…





Grade item	Calculated weight	Grade	Range
Proyecto glossaLAB			
Linear Algebra	-	-	0–100
Physics	-	-	0–100
Digital Signal Processing	-	-	0–100
Curso "Enseña con MATLAB" (2h)	-	-	0–100
Control Engineering I	-	-	0–100
Course total Weighted mean of grades. Include empty grades.	-	-	**0–100**

Create interactive course assignments

Automatically grade student work and provide feedback

Run your assignments in any learning environment

Integrate MATLAB Grader with your LMS

Challenge students with innovative engineering topics

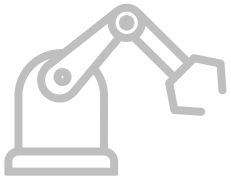
Leverage student programs

Preparation

Lessons

Study

Laboratories



Evaluation

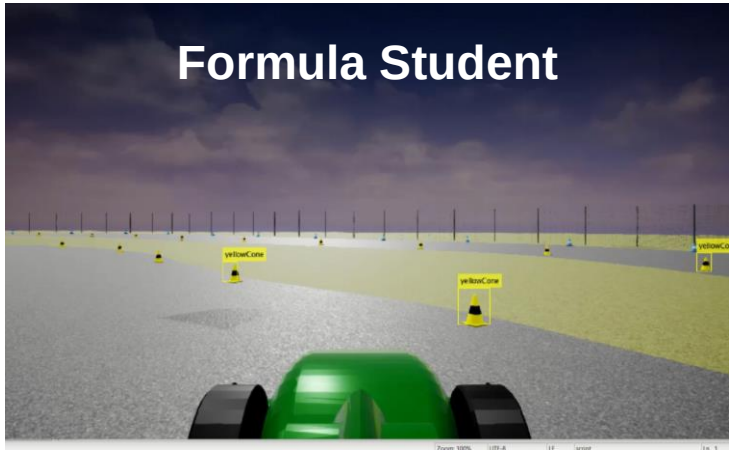
Student Programs

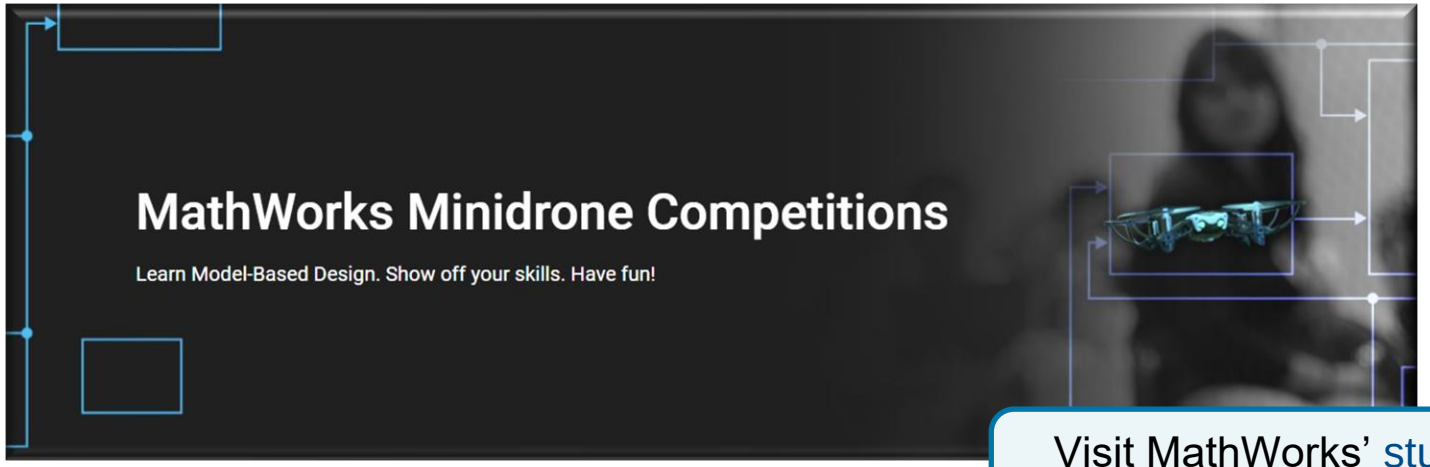
Encourage students to put their knowledge to the test

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



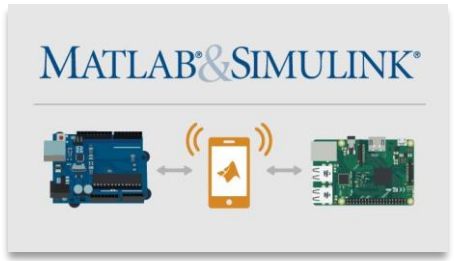


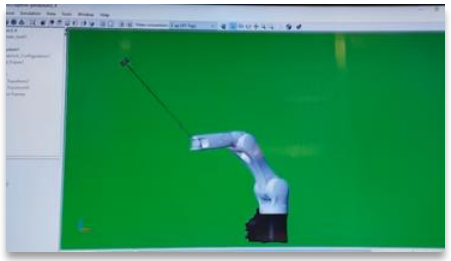
Visit MathWorks' student competitions webpage

Challenge your students

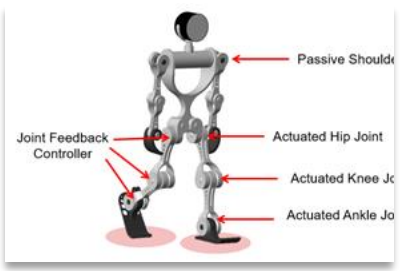
Ideas for research projects, undergraduate/postgraduate final projects…

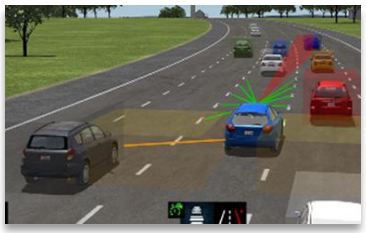
SIMULINK STUDENT CHALLENGE

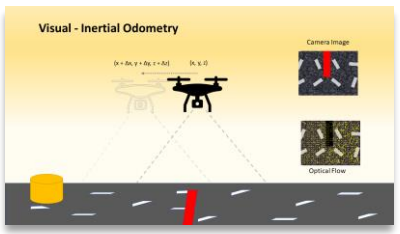




MathWorks Excellence in Innovation Robotics Projects







View the 2022 Simulink Student Challenge winners

Overcome challenges in teaching robotics and controls

Try these MATLAB & Simulink based tools

Preparation

Courseware

Lessons

Interactive notebooks

Cloud resources

Apps

Study

Self-paced online trainings

Tech talks

Laboratories

Virtual labs

Hardware support

Evaluation

Auto-grading

Student Programs

Competitions

Innovation Projects

Build practical engineering skills with MATLAB & Simulink

Mondragon University use Project-Based Learning to teach robotics and controls

*"**Campus-wide access** to MATLAB and Simulink enabled us to develop and implement an educational model founded on **practical**, **project-based learning** that helps students go from merely knowing engineering concepts to knowing how to **apply them**.*

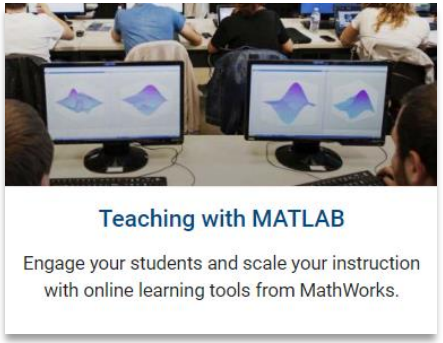
***Companies** that use simulation already and companies looking to lower costs by introducing simulation recognize the benefits of **hiring graduates** who have practical **experience with MATLAB and Simulink**."*

Carlos García
R&D Manager, Faculty of Engineering
Mondragon University

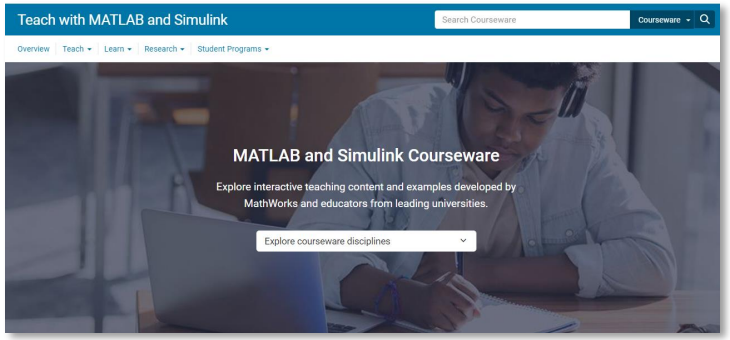
Get started quickly with these teaching resources

Call-to-action

1. Learn more about teaching tools and resources
   Complete the "Teaching with MATLAB" course



2. Visit courseware site for teaching materials
   For controls and robotics



Contact MathWorks for **curriculum development**
Email us at academicsupport@mathworks.com

MATLAB EXPO

Thank you

Join other MATLAB EXPO sessions and demos:

- Interactive Learning with MATLAB Apps, Live Scripts, and MATLAB Grader
- LMS-Based Teaching Tools for Educators