Distance Learning with MATLAB & Simulink: challenges and solutions to prepare the next generation of Engineers

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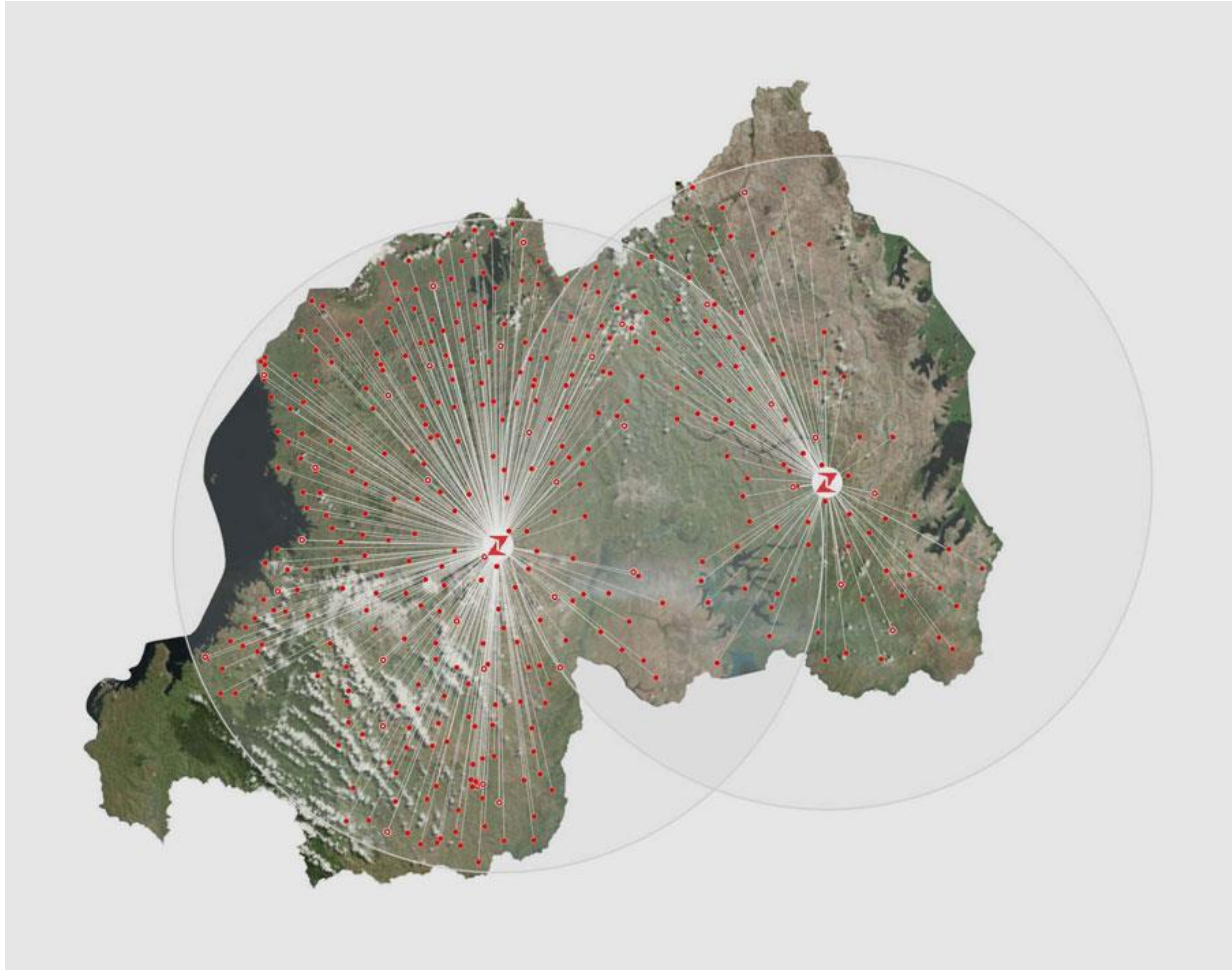
Agenda

- Introduction
- Challenges and Needs in Teaching
- An example: Quadcopter with Pendulum
  - Modelling
  - Control Design
  - Simulation and deployment
- Resources for distance learning
- Summary and Q&A

Let me tell you a story… zipline

The largest autonomous logistic network for medical supplies



All images and videos on this slide are from https://flyzipline.com/

Let me tell you a story… zipline

The largest autonomous logistic network for medical supplies

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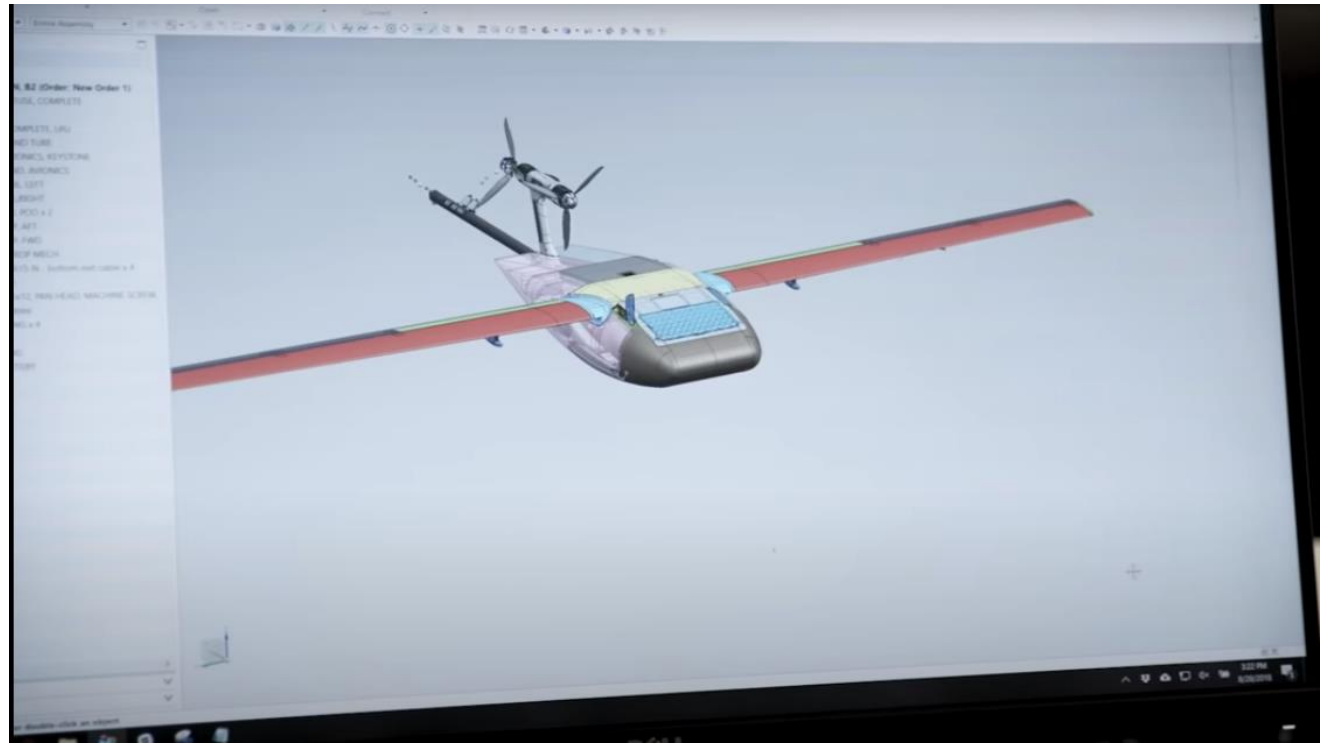
Let me tell you a story… zipline

The largest autonomous logistic network for medical supplies

Some of the technology involved:

- GPS for tracking
- Communication system
- Battery management
- Materials for quick substitution of the drone's parts
- Automatic safety features



Engineers at Zipline have used MATLAB and Simulink to test the drone in a number of different scenarios and optimise the algorithms.

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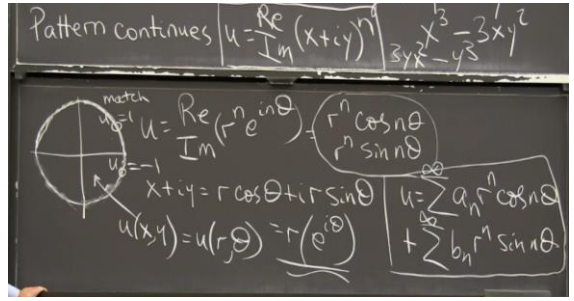
What Tomorrow's Engineers and Scientists Need to Know?



- Control, Signal Processing, Optimization, Computer Vision
- Abstraction, Modelling, and Simulation

AND

- Multidomain System Development

AND

- Distributed and Connected Systems
- Using Cloud Platforms and Big Data Processing
- AI and Data Science

Challenges in **Online** Teaching

- Engagement with students, keep them motivated
- Development of skills in real-problem scenarios to get ready to industry

- Virtual Laboratories
- Remote classes
- Remote exams

Project-Based Learning

Treat engineering students like engineers

Hands-on experience of working on hardware and software

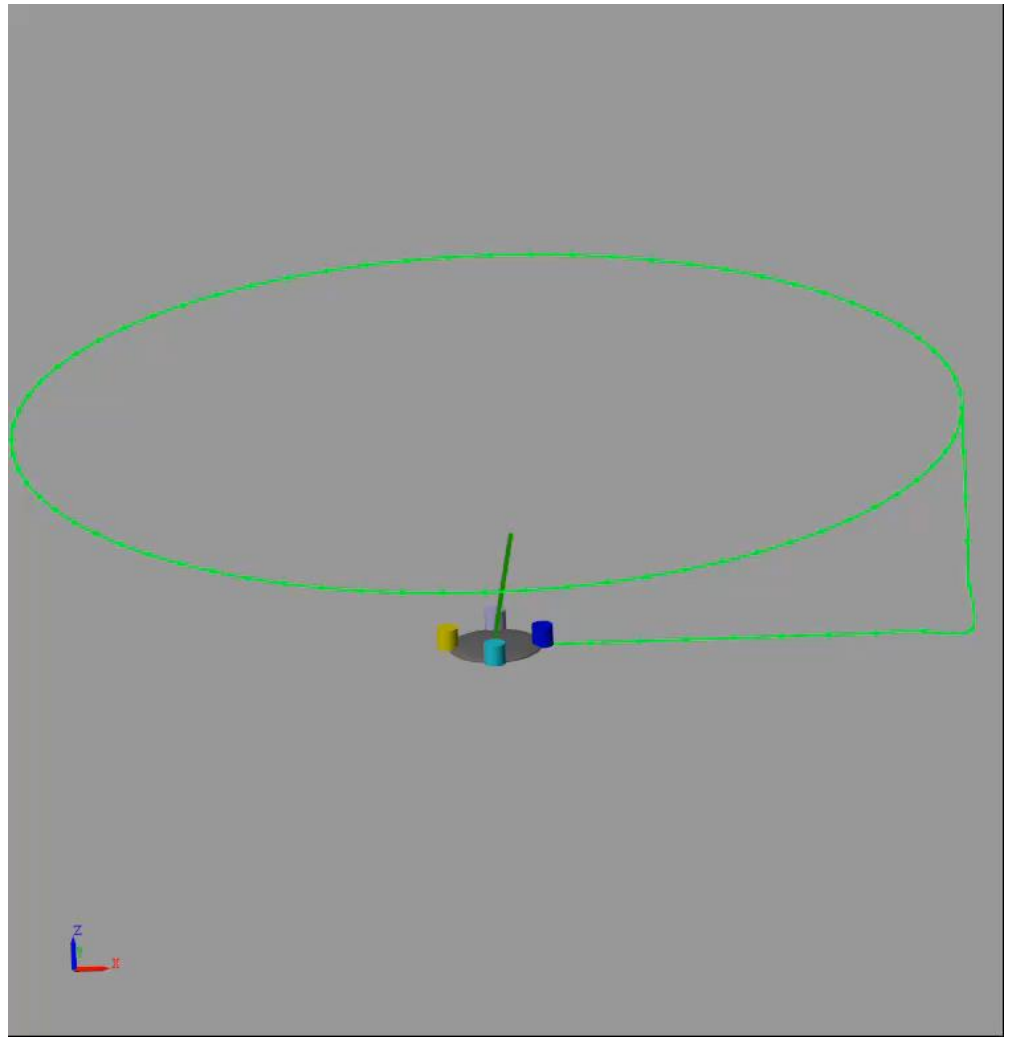
Solve authentic problems in myriad contexts

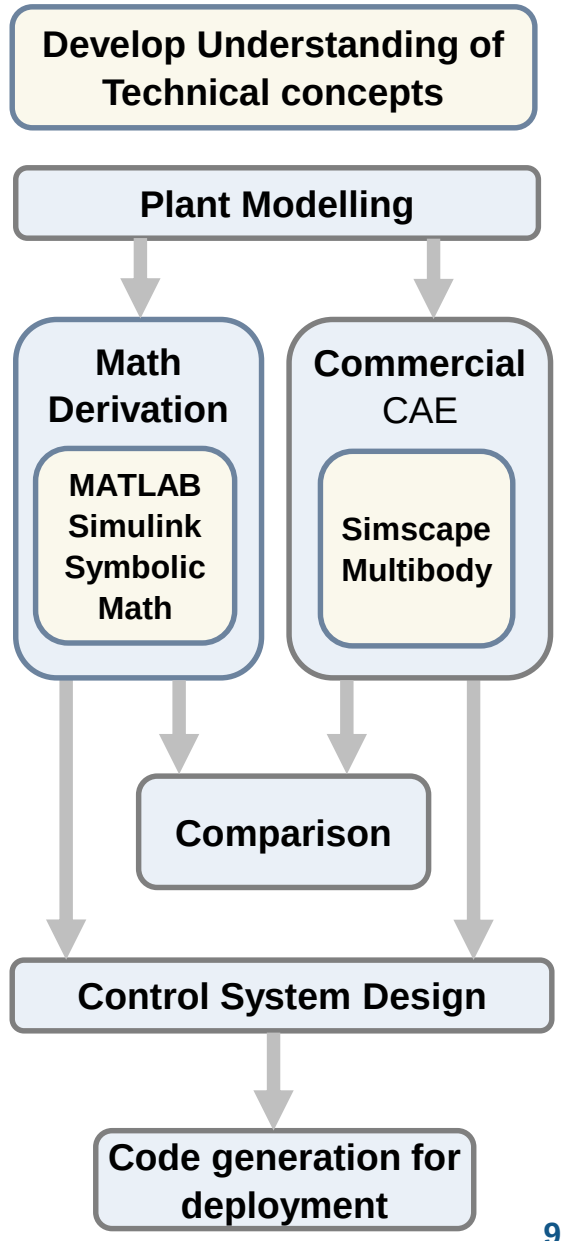
Increase student interest and improve learning

Let's consider an example…
Quadcopter with Pendulum Simulation

Learning Objectives

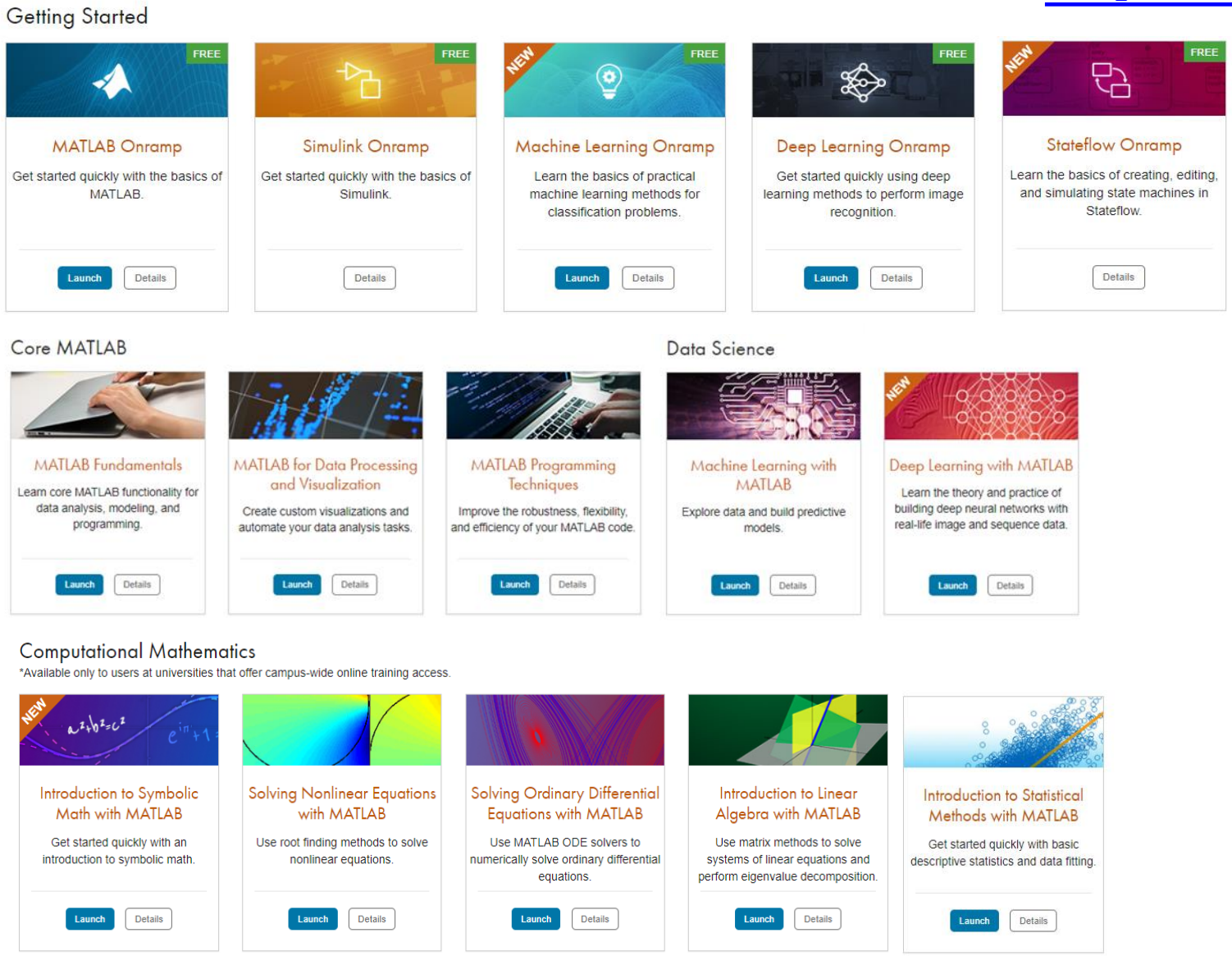
- Develops Computational Thinking for complex systems
- Enables comparisons of theory and simulation
- Principles of control and path planning





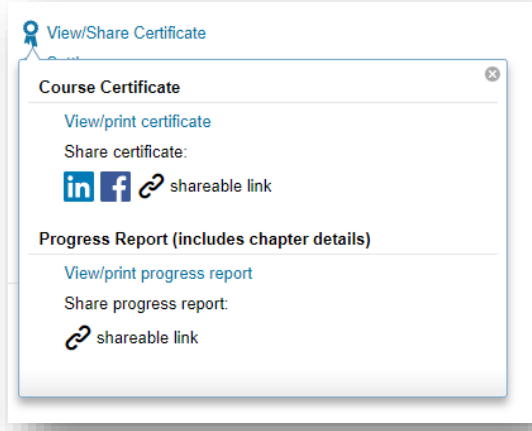
How can students ramp up/refresh their MATLAB and Simulink skills?

https://matlabacademy.mathworks.com/

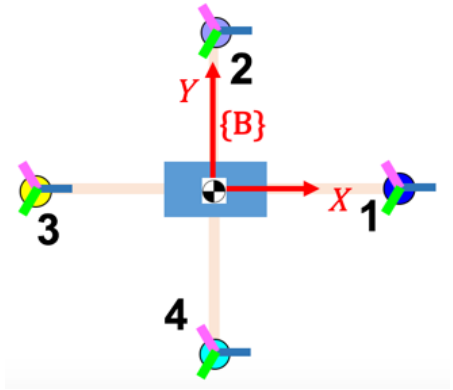


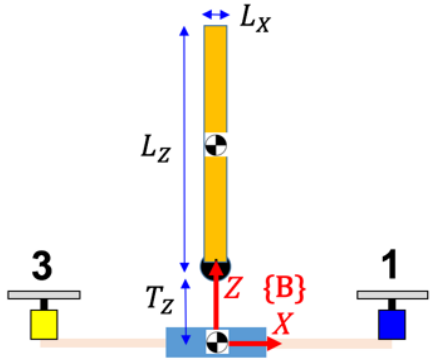
Online Self-Paced Interactive Training
~2 h each

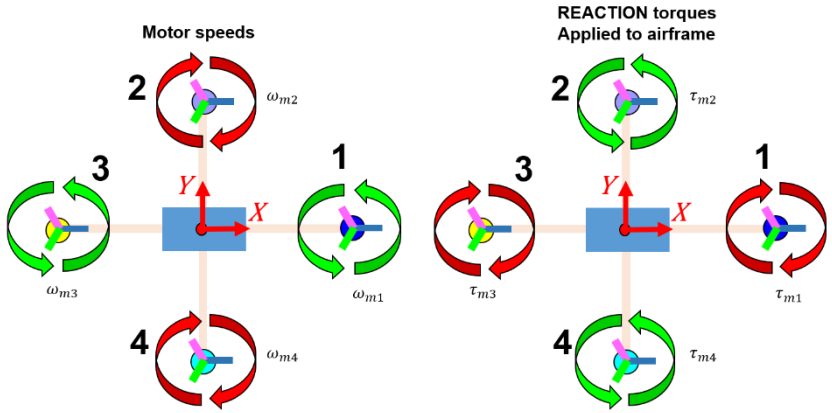
~10 -15 h each



Quadcopter with Pendulum Simulation - Modelling Part 1







1 Airframe
4 Propeller assemblies
1 Pendulum

Euler-Lagrange

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{q}_k} - \frac{\partial L}{\partial q_k} = Q_k \qquad k = 1, 2, \ldots, n$$

Generalised forces

$$Q_k = \sum_{i=1}^{Nf_{nc}} \left(\vec{F}_i \cdot \frac{\partial \vec{v}_i}{\partial \dot{q}_k} \right) + \sum_{j=1}^{N\tau_{nc}} \left(\vec{\tau}_j \cdot \frac{\partial \vec{\omega}_j}{\partial \dot{q}_k} \right)$$

Kinetic energy

$$\mathrm{KE}_i = \frac{1}{2} v_{\mathrm{cm}_i}^T . m_i . v_{\mathrm{cm}_i} + \frac{1}{2} . \omega_{B_i}^T . \left[I_{\mathrm{cm}_i} \right] . \omega_{B_i}$$

Potential energy

$$PE_i = g \cdot m_i \cdot h_i$$

Develop Understanding of Technical concepts

Plant Modelling

Math Derivation

MATLAB Symbolic Math Simulink

Commercial CAE

Simscape Multibody

Comparison

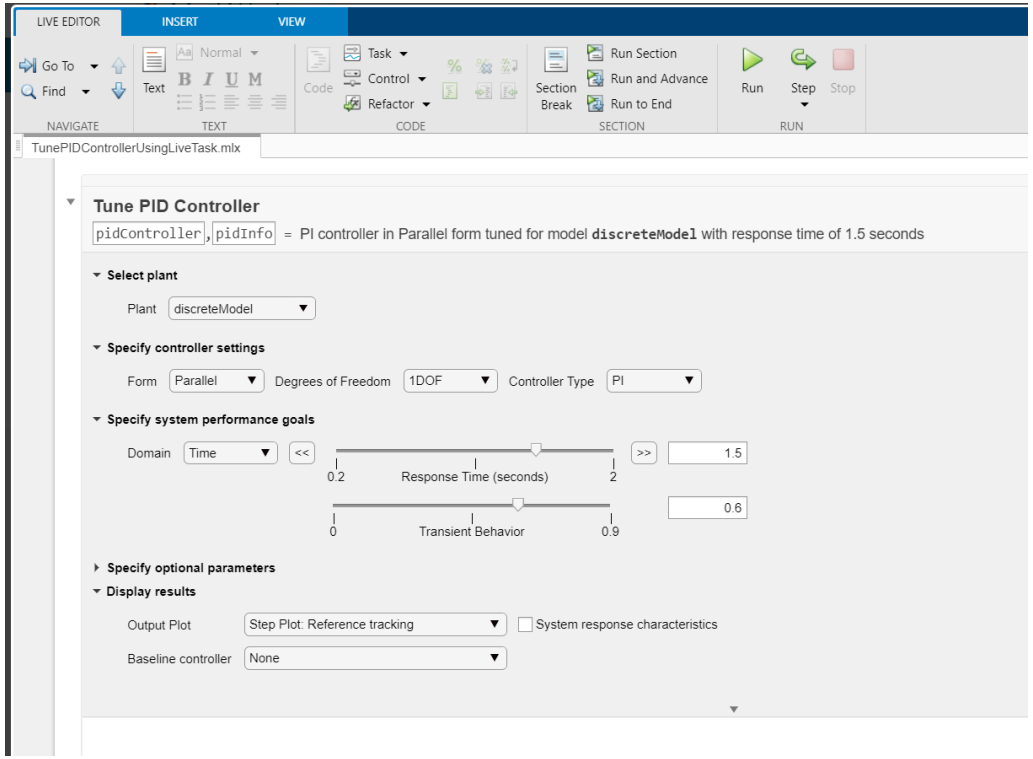
Control System Design

Code generation for deployment

How to keep students engaged during lectures?

Live Scripts

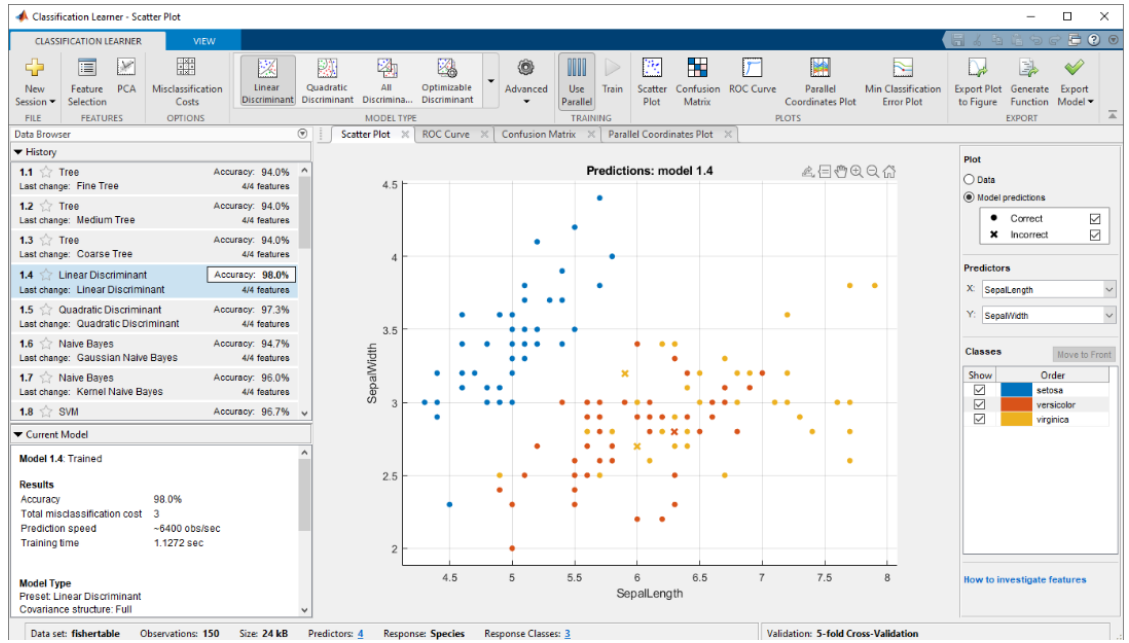
Interactive executable notebooks with code, text, figures, outputs all in a single document. Students can experiment with parameters and see the results immediately in the same document



[Tune PID Controller from Measured Plant Data]

MATLAB Apps

Built-in or customised user-interfaces that allow students to interact with the material and develop an intuition before getting into the specifics of equations or algorithms.

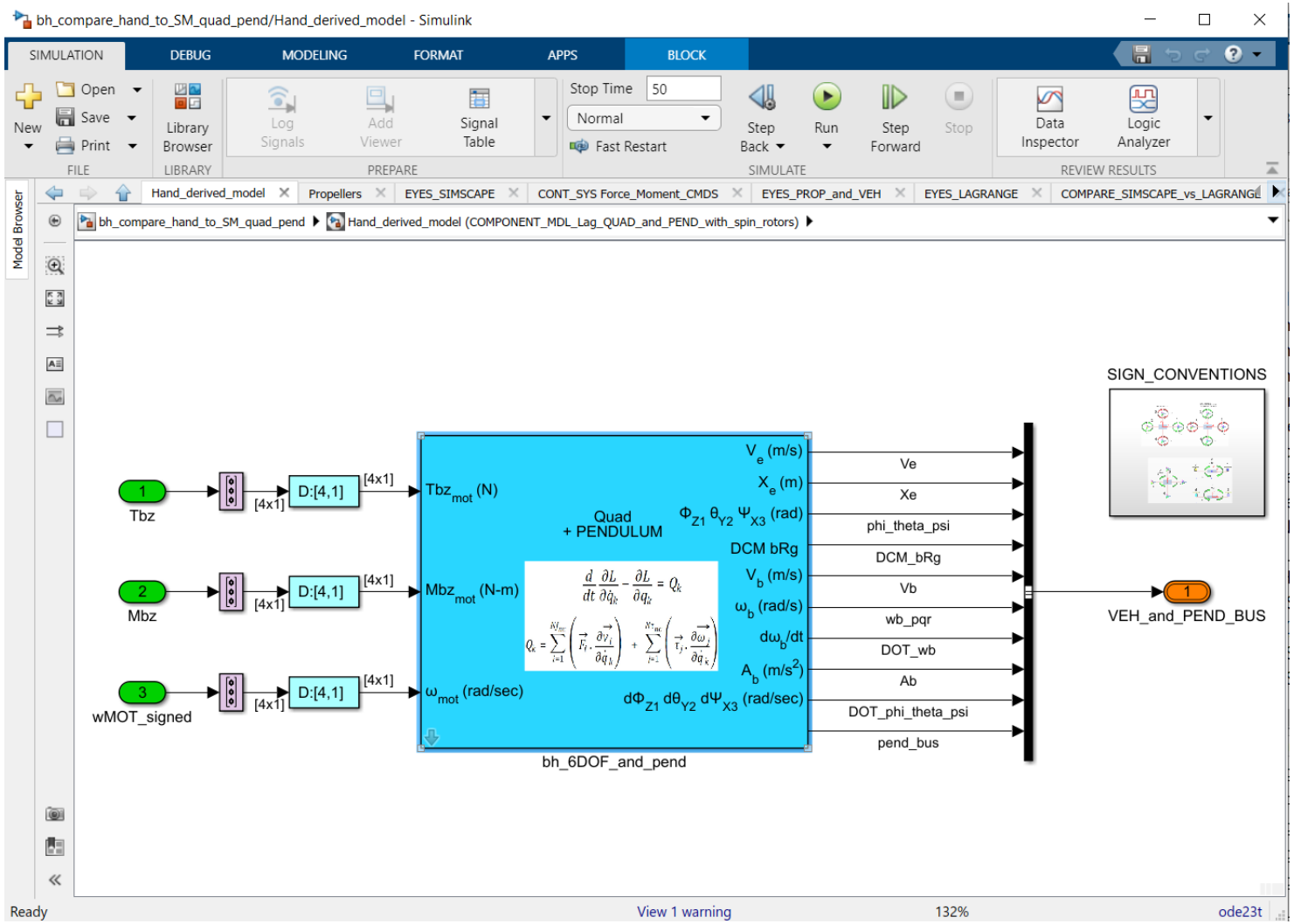


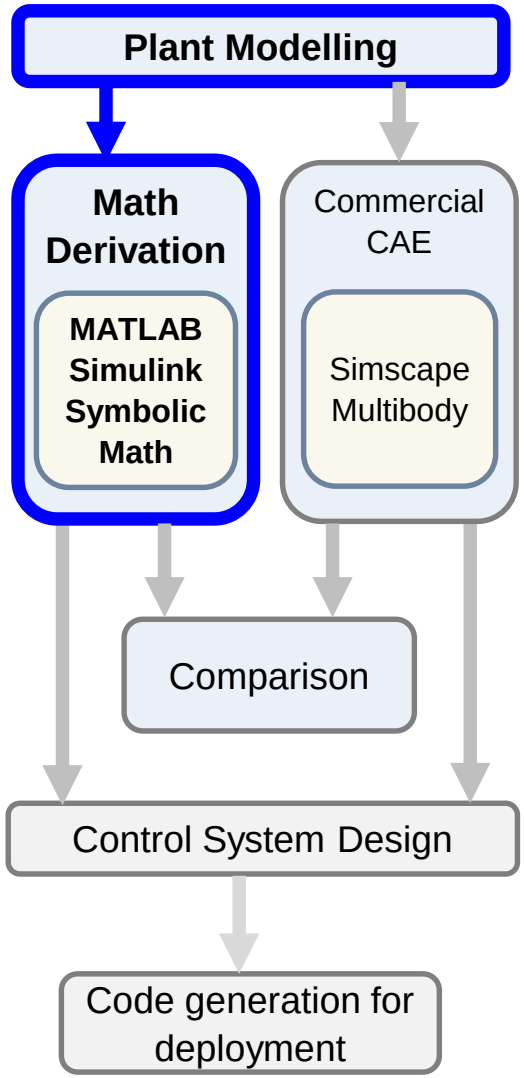
[Machine Learning model for classification]

Quadcopter with Pendulum Simulation - Modelling Part 2

Develop Understanding of Technical concepts

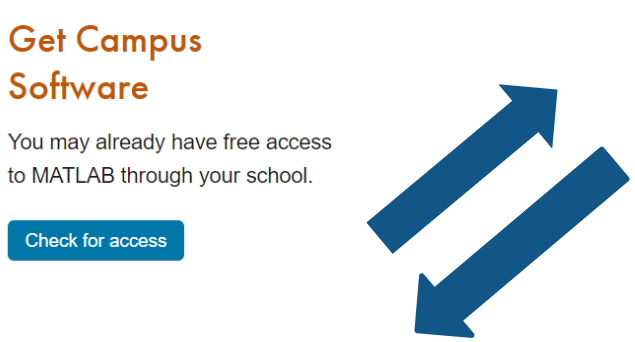
Implementation of Euler-Lagrange with blocks in Simulink





How can students can access MATLAB & Simulink remotely? How do I share the scripts and models with students?

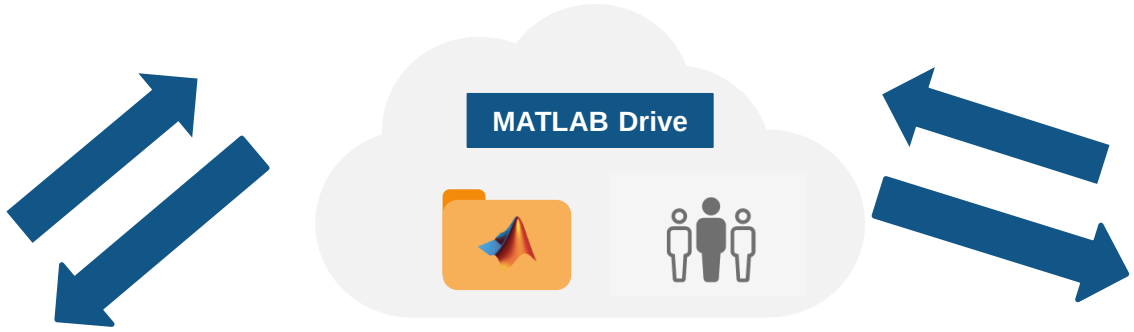
- Students and Staff have access to MATLAB for free



[Campus-Wide Licence](#)

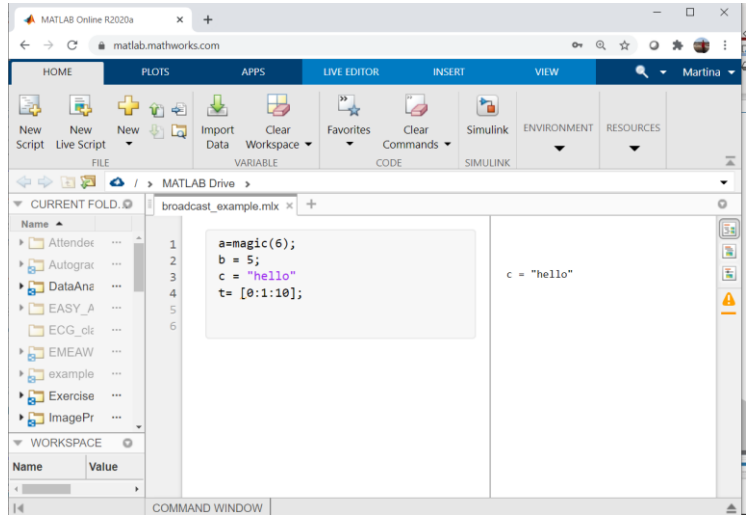
Download MATLAB on your PC using your University email address

Possibility to use Source Control (e.g. Git, SVN) on MATLAB Desktop



Sync and share your MATLAB code and Simulink models with [MATLAB Drive](#)

Access [MATLAB and Simulink Online](#)

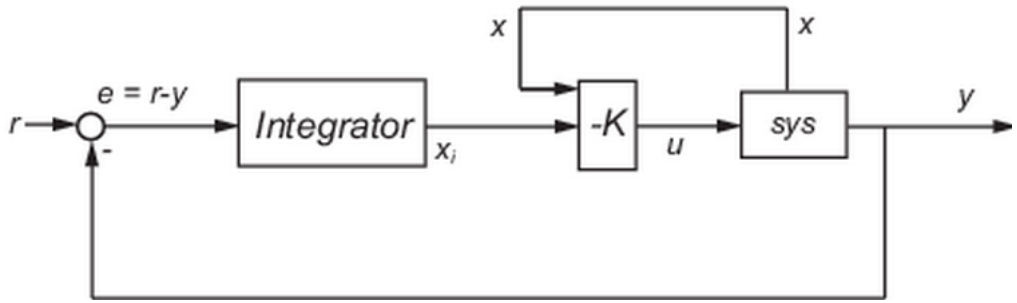


Access [MATLAB Mobile](#)

Learn and practice anywhere, anytime!

Quadcopter with Pendulum Simulation - Control Design

Develop Understanding of Technical concepts



LQI control

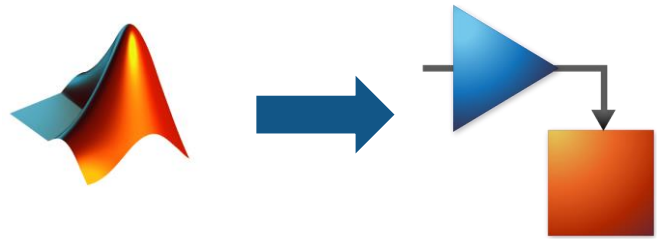
State-space equations

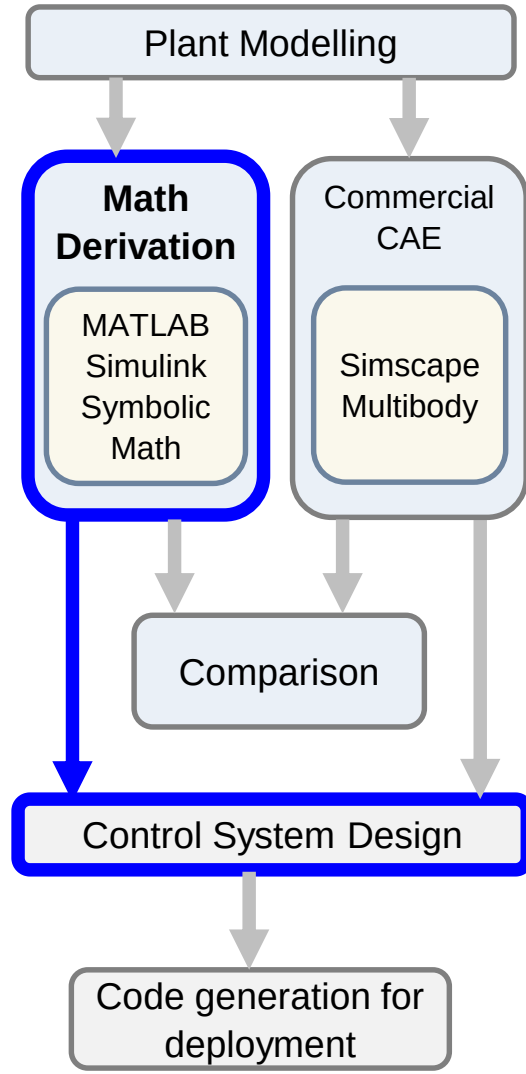
$$\frac{dx}{dt} = Ax + Bu$$
$$y = Cx + Du$$

State-feedback control

$$u = -K\,[x; x_i]$$

- Linearize the model
  - 4 Inputs
  - 3 Outputs
  - 18 States
- Discretise
- Set weighting matrices Q and R



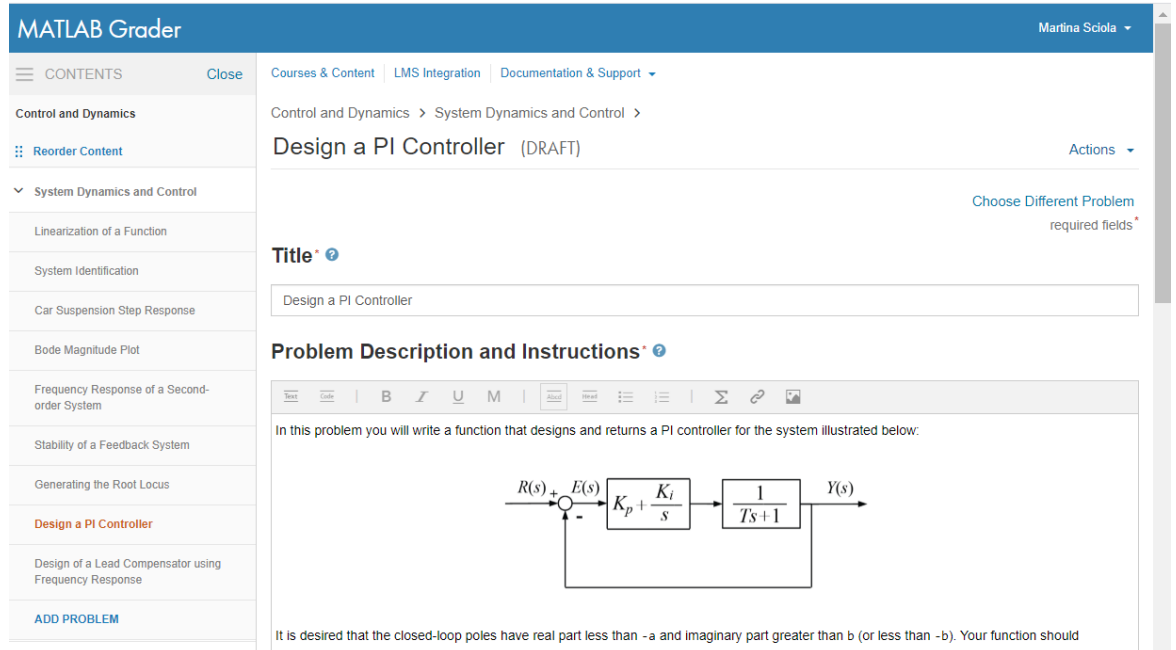


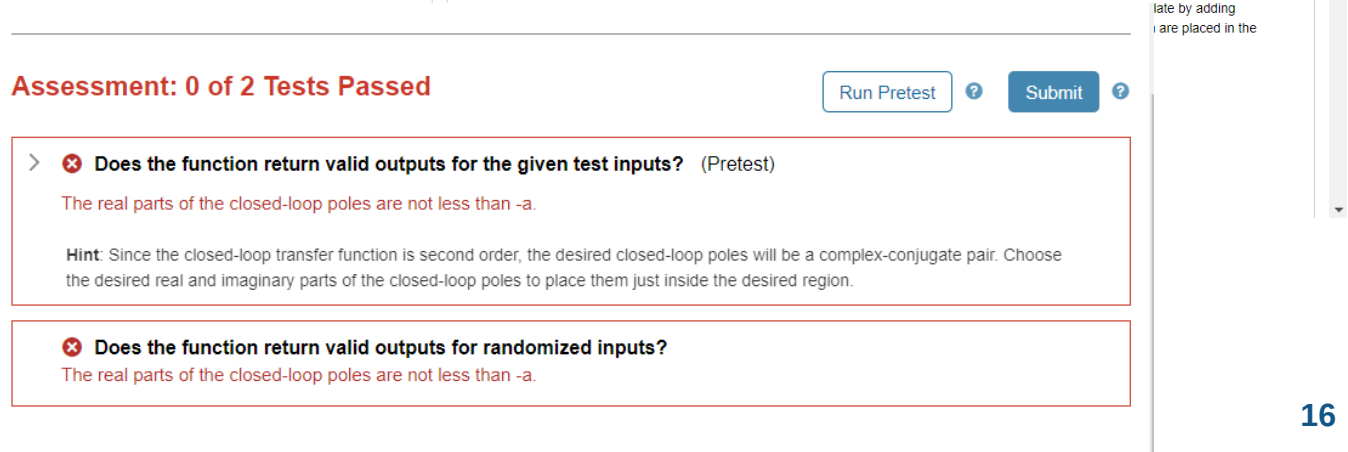
How can I assess my students and build their confidence with immediate feedback?

https://grader.mathworks.com

MATLAB Grader: a tool to save time grading MATLAB code and provide immediate feedback to students

- Creation and sharing of **MATLAB-based assignments**
- A library of **re-usable examples**
- **Autograded student solution** with custom scoring rubrics
- View **student performance analytics** at the individual and aggregate levels
- **Learning Management System Integration with Campus-Wide Licence**





Quadcopter with Pendulum Simulation - Modelling Part 3

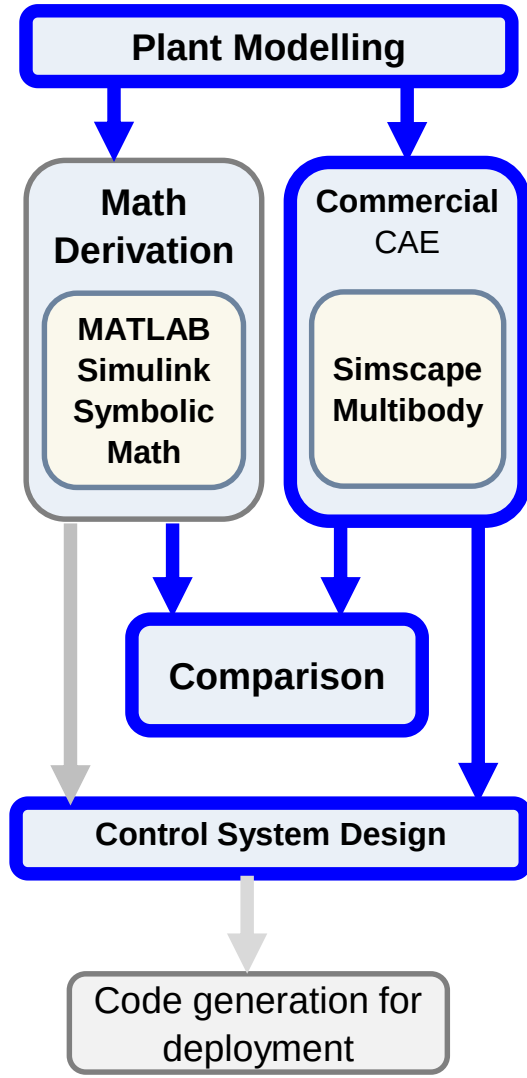
Develop Understanding of Technical concepts

Simscape Multibody: multibody simulation environment for 3D mechanical systems and integrate with hydraulic, electrical, pneumatic, and other physical systems

Multidisciplinary projects can speak the same language!

- Simulate in a virtual environment
- Test the model under indefinite number of conditions

Industry	Academia
Model-Based Design	**Virtual and Remote Laboratory**



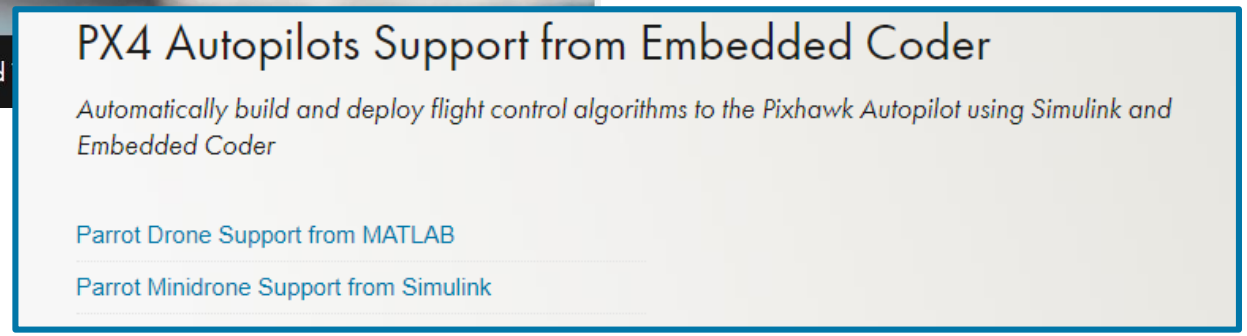
Quadcopter – Code generation and deployment

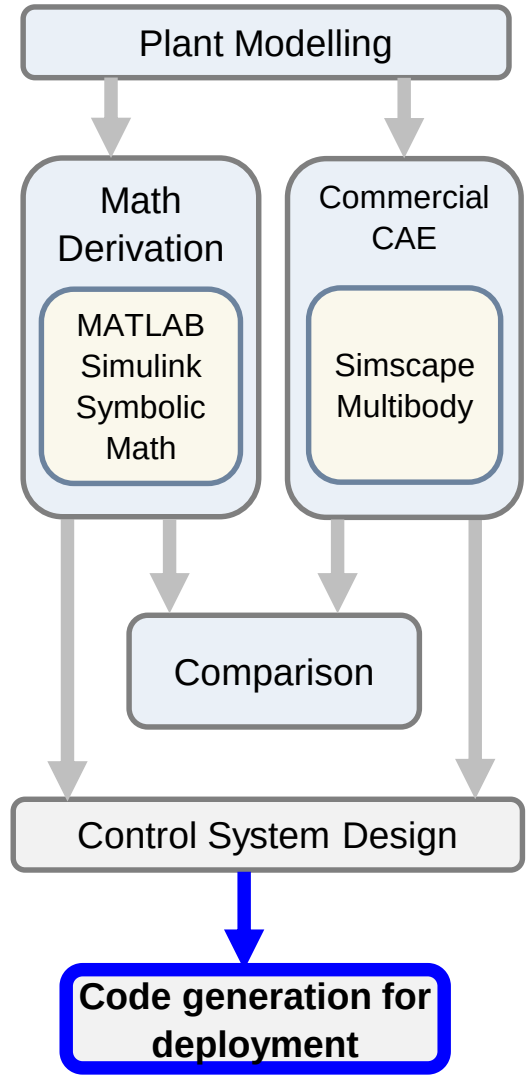
Develop Understanding of Technical concepts

Easily and quickly **generate code** and **deploy** it to **target hardware** with **Code Generation!**

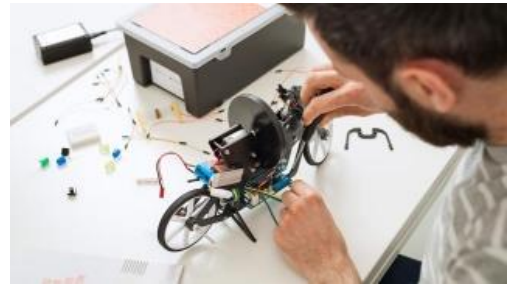
https://www.mathworks.com/hardware-support/home.html

- C/C++
- HDL
- PLC
- See complete list of Code Gen Toolbox here!





How to include data collection experience in remote teaching?

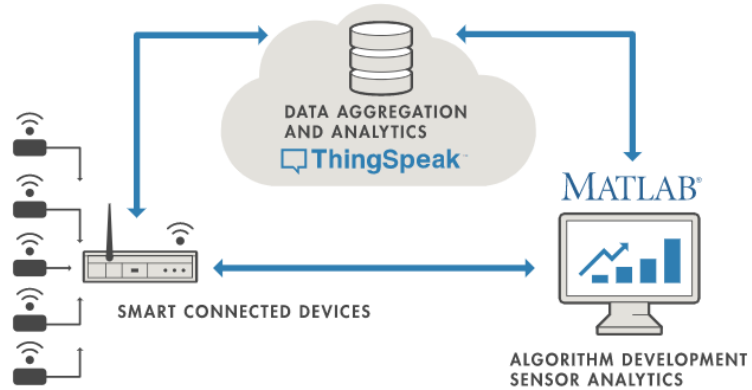


- Low-cost hardware at home (i.e. Arduino, Raspberry PI)

- Share protected Simulink models, where students provide inputs and gather output without having access to the details of the model

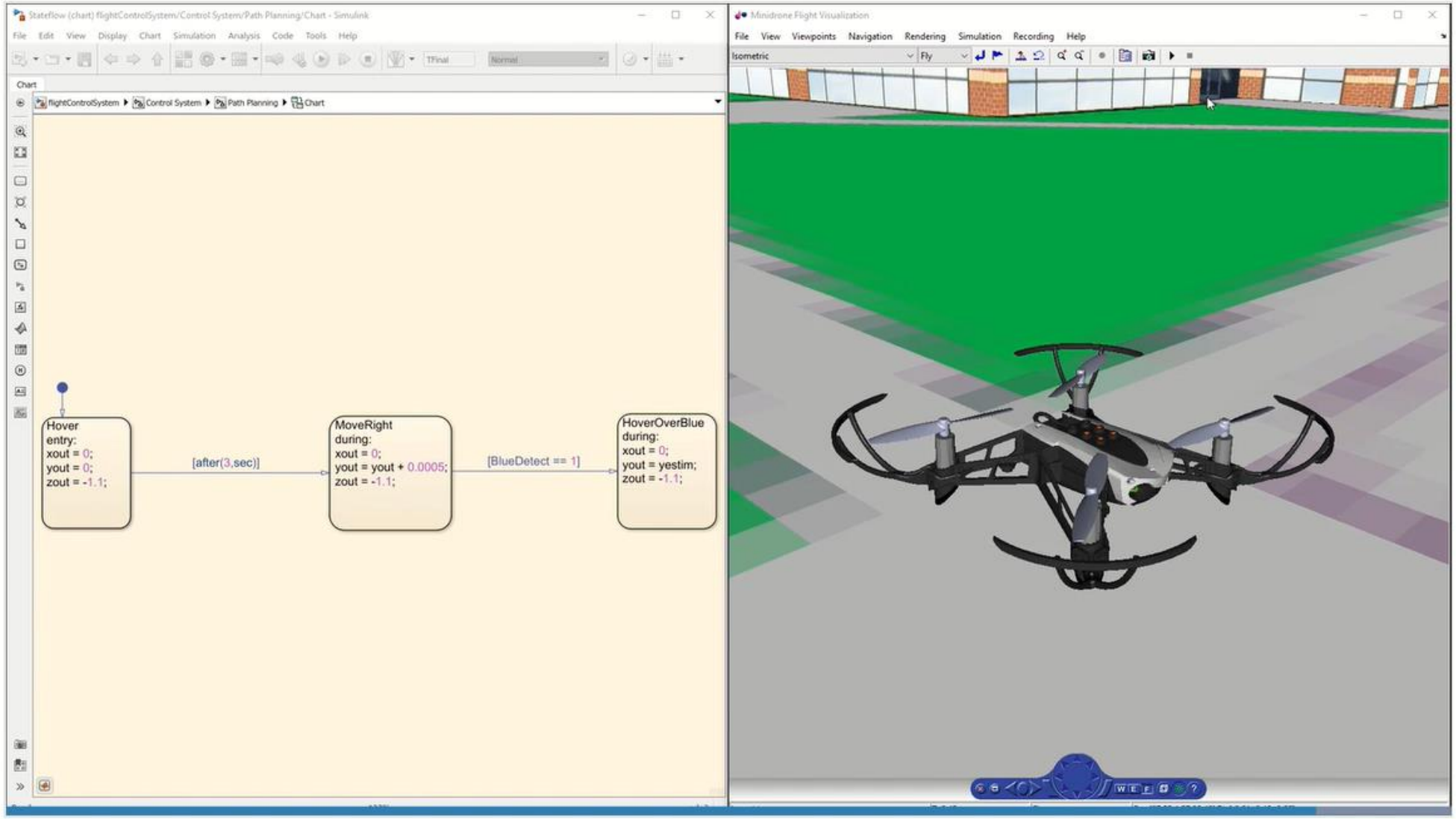
[Experience from Prof. Yossi Chait at University of Massachusetts Amherst]

- [Thingspeak]: IoT analytics platform service that allows you to aggregate, visualize and analyze live data streams in the cloud.



Virtual Laboratories with MATLAB and Simulink

Path Planning and Motion Control with State Machines using Stateflow

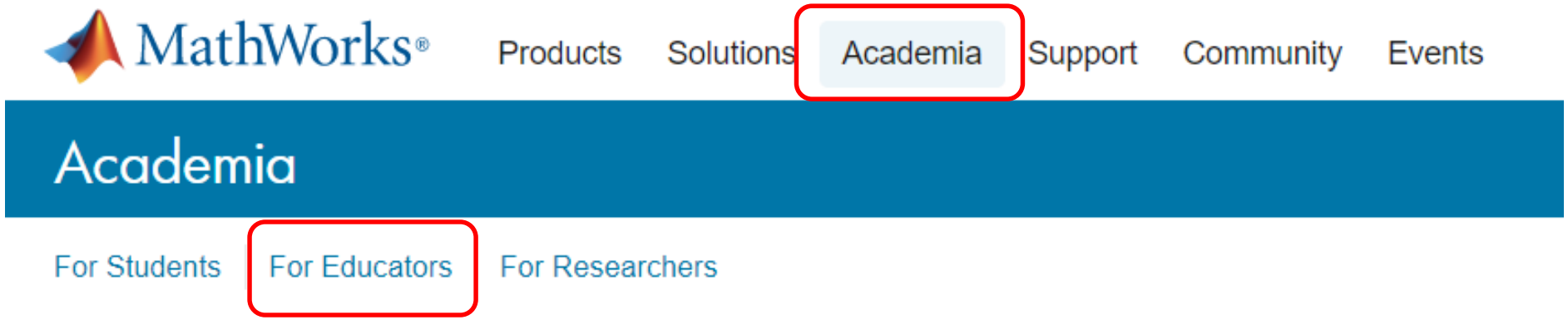


Resources for Distance Learning

- Self-Paced Online Trainings: browser-based interactive courses with immediate feedback
- MATLAB Online/Simulink Online: use MATLAB and Simulink from the browser
- MATLAB Mobile: use MATLAB from your smartphone
- MATLAB Drive: sync and share your projects
- MATLAB Grader: autograde MATLAB code and provide immediate feedback
- Thingspeak: IoT platform to visualise and analyse data
- Distance Learning Community: discover how academics are preparing for remote teaching

Other Teaching Resources

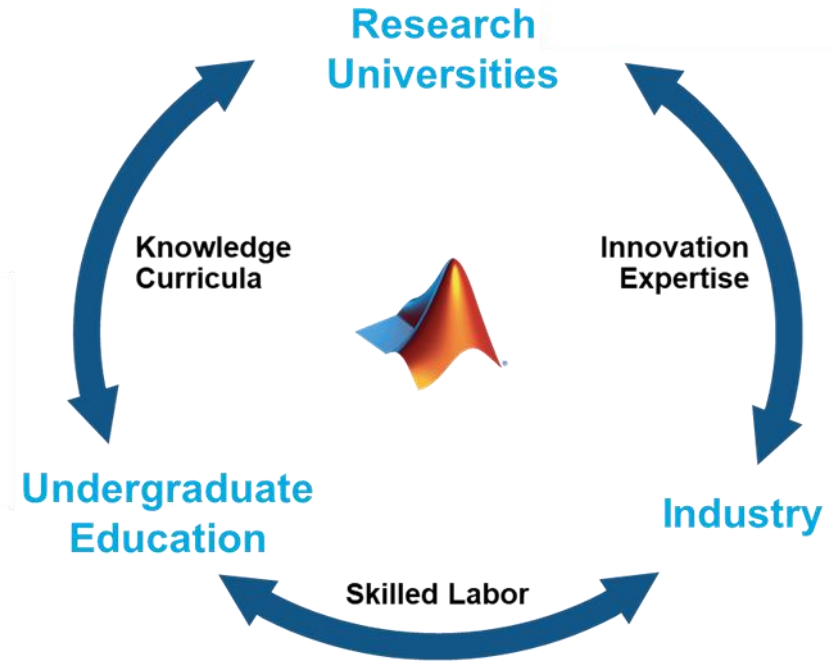
- Live Scripts: interactive scripts with code, images, text, etc.
- MATLAB Apps: interactive graphic application for technical computing tasks
- Courseware: repository of downloadable teaching material from academics
- Control Tutorials: tutorials and curriculum on system dynamics and control



https://www.mathworks.com/academia.html

Key Takeaways

- Digital Transformation is revolutionizing the industry
- New graduates will be expected to address more complex and multidisciplinary challenges
- Experience with tools and workflows used in industry make students more hireable



THANKS FOR YOUR ATTENTION

Any questions?

https://www.mathworks.com/support/contact_us

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Quadcopter with Pendulum Simulation - Control Design

Develop Understanding of Technical concepts