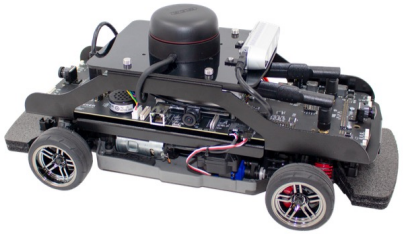
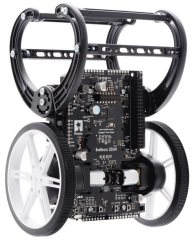
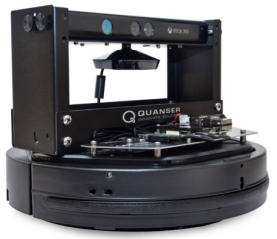
Control of mobile robots







Hugues GARNIER

hugues.garnier@univ-lorraine.fr

12 September 2023

Volumes horaires

- ***Contrôle de robots mobiles***
  - 1 séance de cours/TD *de 2h* 2h
  - 8 séances de TP *de 4h* *32*h

  Supports de cours en anglais

- - - - - - - - - - - - -

- Intervenants en cours/TD
  - Hugues Garnier
- Intervenants en TP
  - Hugues Garnier (5 premiers TP)
  - Mayank Jha (3 derniers TP)

Contrôle des connaissances

- 2 compte-rendus (CR) de TP
  - A faire en binôme
- 1 présentation orale d'un des TP
  - A faire en binôme/trinôme
- Calcul de la note finale

Note EC = 0,3 CR TP1 + 0,3 CR TP2 + 0,4 Oral

Website for the course : *Labs & tutorials*

- **w3.cran.univ-lorraine.fr/hugues.garnier/?q=content/teaching**

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Hugues Garnier

Navigation

Add content

Teaching

Basic page *Teaching* has been updated.

View Edit

Teaching activities

Since 2018, I am head of the 3-year engineering programme (see pdf) in *Computer Science, Control Engineering, Robotics, IT Networks (IA2R)* at Polytech Nancy.

I teach the following courses:

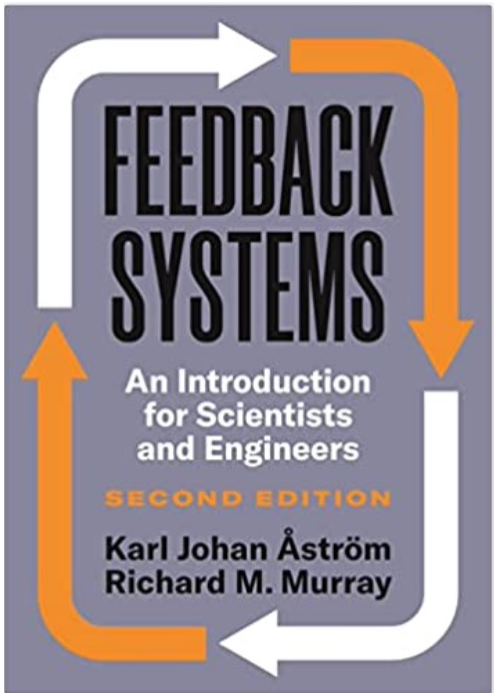
Control of Mobile Robots (5A IA2R Parcours SIA)

- Tutorials
- Labs
  - Lab n°1 - The Qcar
  - Lab n°2 - The Qbot
  - Lab n°3 - The 3pi+
    - File for 3pi+
- Feedback about the course from the students
  - Feedback from students 2021-2022

Recommended book in Control

Feedback Systems

An Introduction for Scientists and Engineers, *K.J. Astrom & R. Murray 2021*



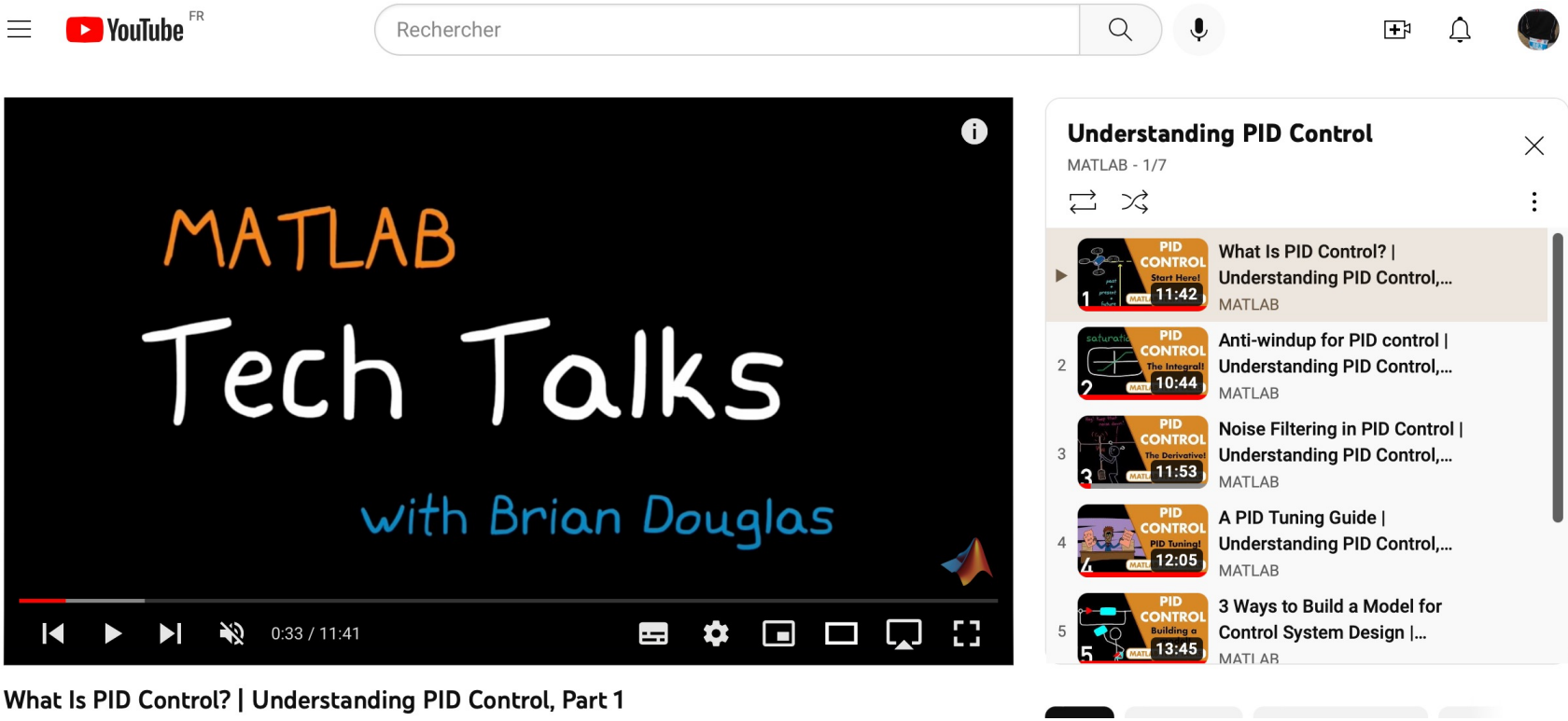
pdf version of the book available

http://www.cds.caltech.edu/~murray/books/AM08/pdf/fbs-public_24Jul2020.pdf

Other ressource recommended in Control

Matlab Tech Talks with *Brian Douglas*

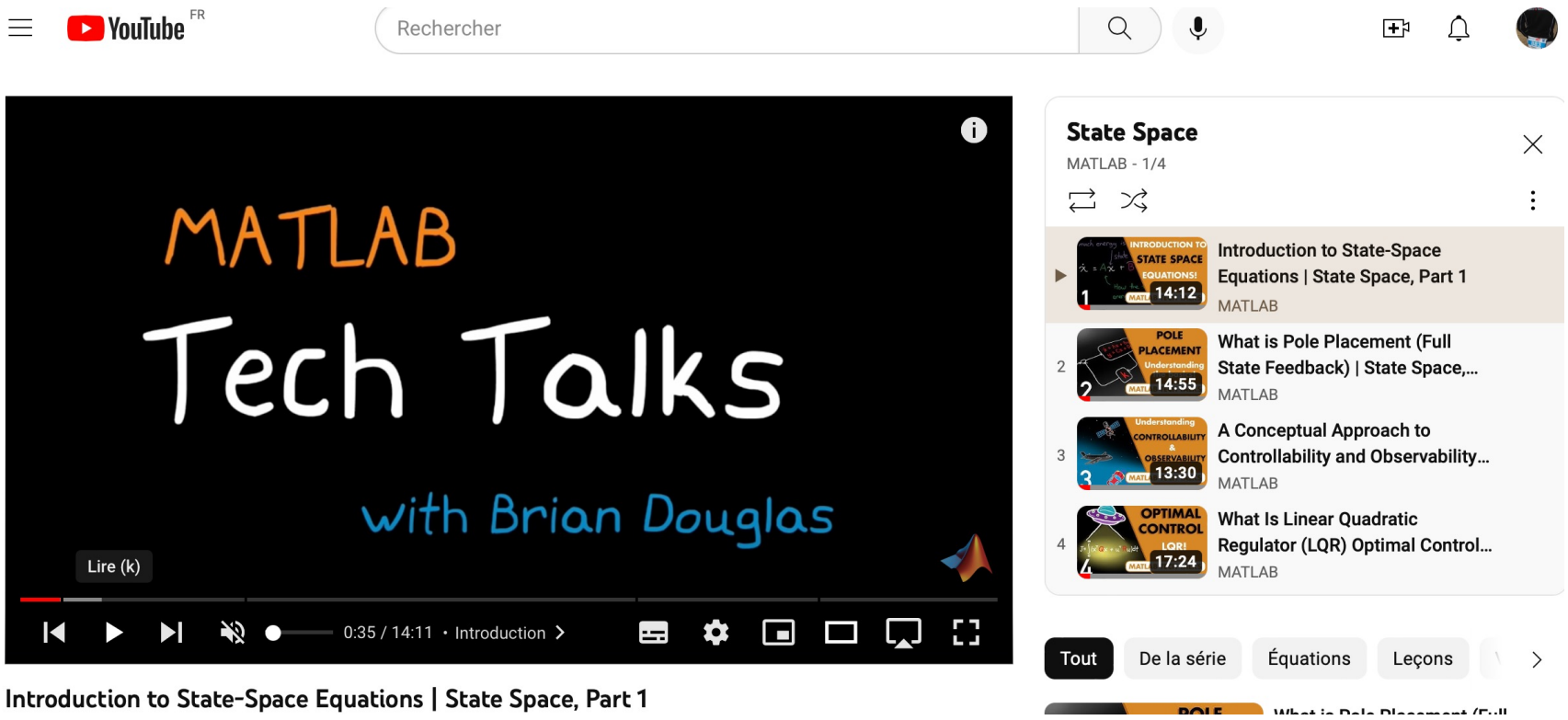
Understanding PID control



Other ressource recommended in Control

Matlab Tech Talks with *Brian Douglas*

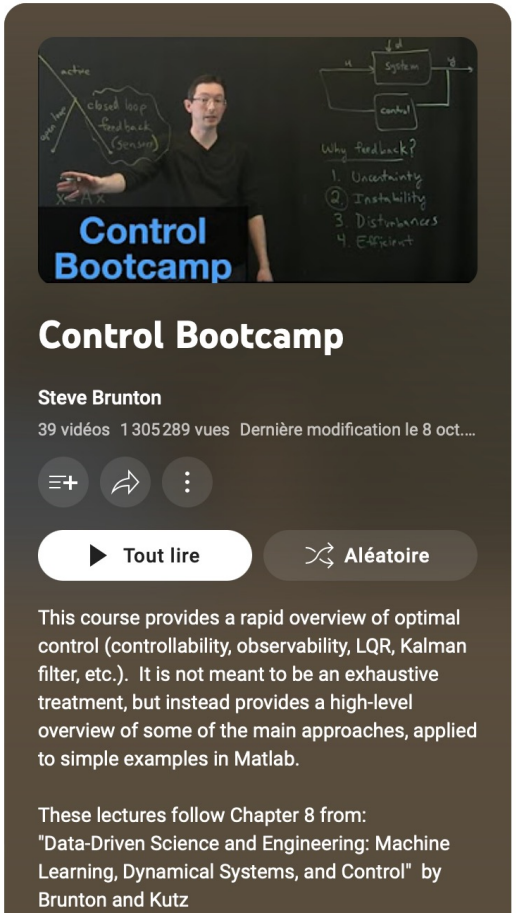
State Space

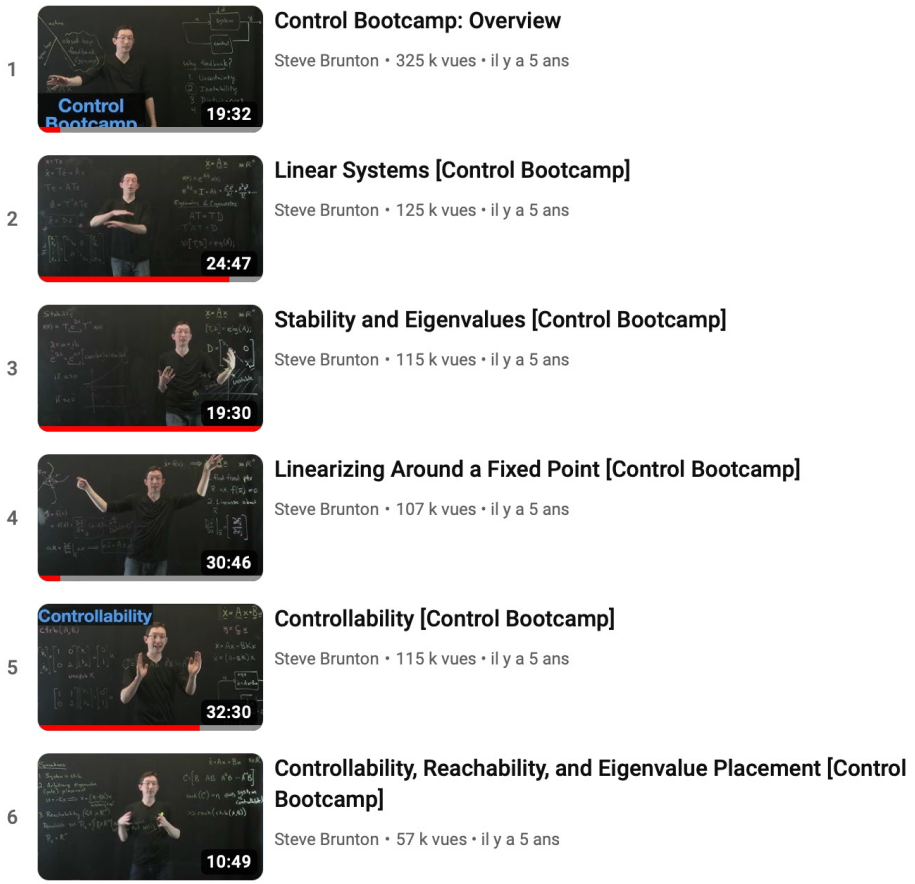


Other ressource recommended in Control

Youtube channel by *Steve Brunton*

- https://www.youtube.com/playlist?list=PLMrJAkhIeNNR20Mz-VpzgfQs5zrYi085m

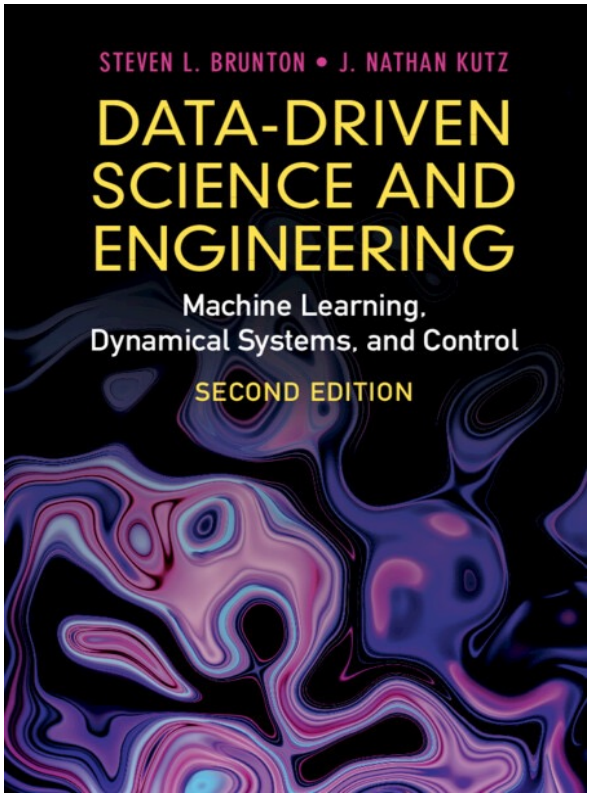




Other book recommended

Data-Driven Science and Engineering

Machine Learning, Dynamical Systems, and Control *S. Brunton & N. Kutz 2022*



Part I. Dimensionality Reduction and Transforms:
1. Singular Value Decomposition
2. Fourier and Wavelet Transforms
3. Sparsity and Compressed Sensing

Part II. Machine Learning and Data Analysis:
4. Regression and Model Selection
5. Clustering and Classification
6. Neural Networks and Deep Learning

Part III. Dynamics and Control:
7. Data-Driven Dynamical Systems
8. Linear Control Theory
9. Balanced Models for Control

Part IV. Advanced Data-Driven Modeling and Control:
10. Data-Driven Control
11. Reinforcement Learning
12. Reduced Order Models (ROMs)
13. Interpolation for Parametric ROMs
14. Physics-Informed Machine Learning

Other ressource recommended in Control :
Textbook available from ***Quanser***

Experience Controls by Quanser

Experience Controls is a free mobile textbook designed to give you real design intuition and relevant skills in a hands-on way in the control systems engineering space.

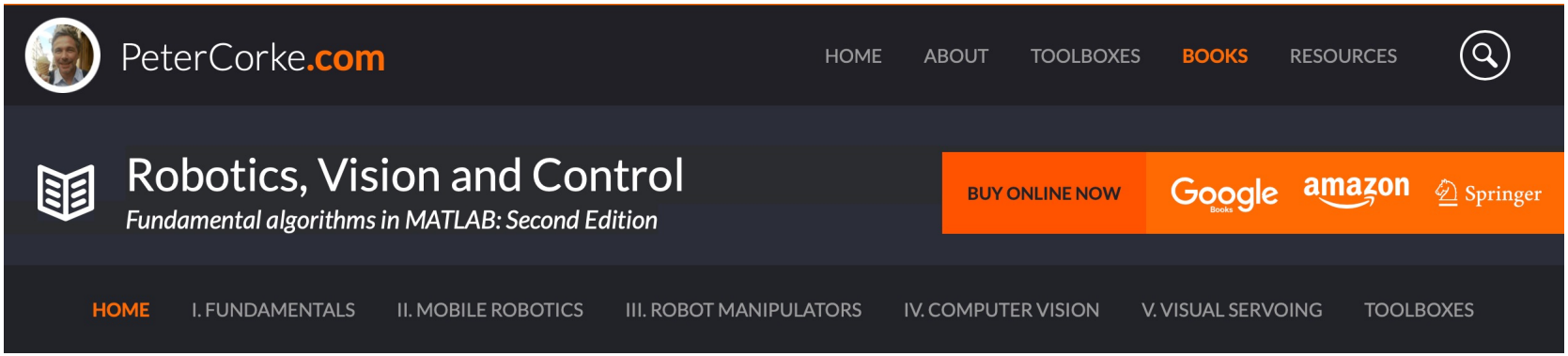
The textbook app includes:

- 50+ lesson modules covering introductory to advanced concepts
- Interactive simulations of industrial-level controls problems
- Mini-lecture podcasts that summarize key takeaways for each chapter, available in-app or in your preferred podcast player
- End-of-chapter review questions to check your understanding

Download on the App Store

GET IT ON Google Play

Recommended book in mobile robots



Home

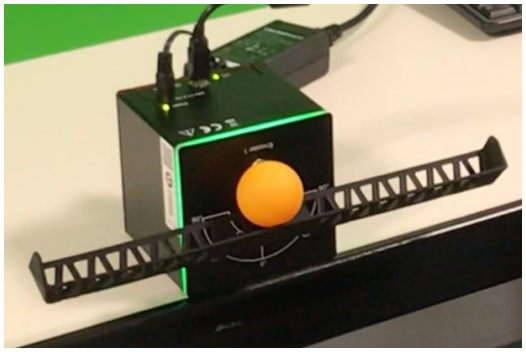
This book makes the fundamental algorithms of robotics, vision and control accessible to all. It weaves together theory, algorithms and examples in a narrative that covers robotics and computer vision separately and together. The author shows how complex problems can be decomposed and solved using just a few simple lines of code, supported by two MATLAB® Toolboxes. The topics covered are guided by real problems observed by the author over many years as a practitioner of both robotics and computer vision.

It is written in a light but informative style, it is easy to read and absorb, and includes over 1000 MATLAB® and Simulink® examples and figures. The book is a walk through the fundamentals of mobile robots, navigation, localization, arm-robot kinematics, dynamics and joint level control, then camera models, image processing, feature

Mobile robots used during the first 2 labs

The QUBE-Servo 2

The Ball & Beam



Lab 1 - PID angular position control of the QUBE inertia disk

Instrumentation

- Hardware
- Software

Modeling

- Transfer function Modeling
- Model identification from Step response

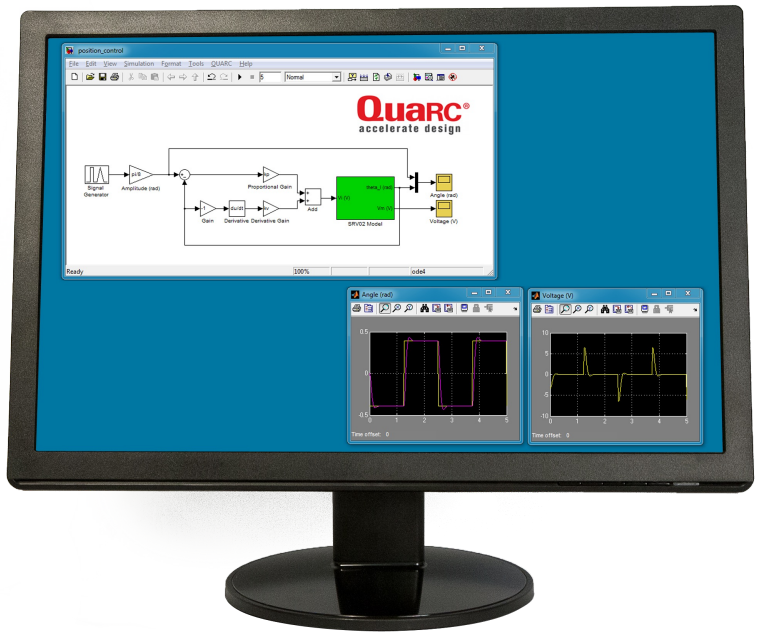
Control Design

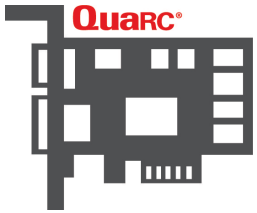
- P and PD control by pole placement

QUARC

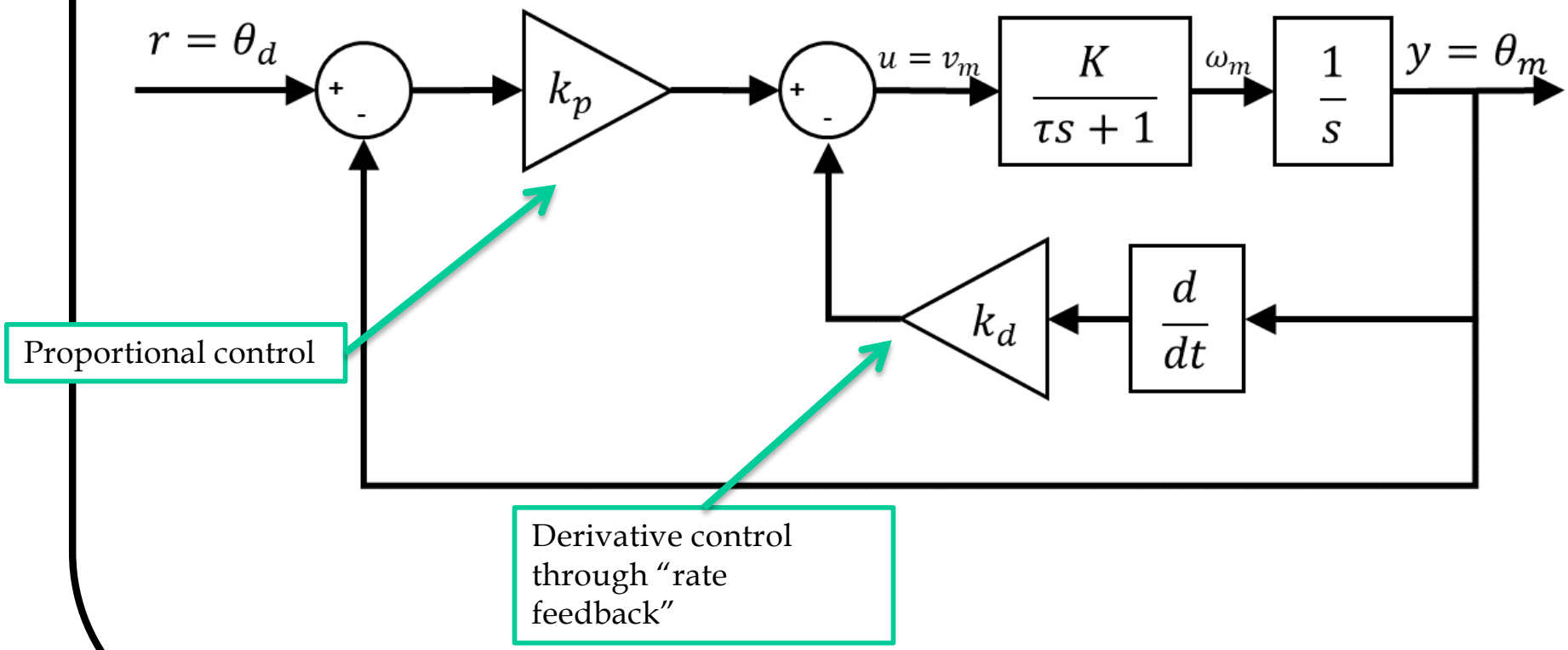
- QUARC is a Rapid Control Prototyping Software made by Quanser for Matlab/Simulink

- Generates real-time code from a Simulink diagram

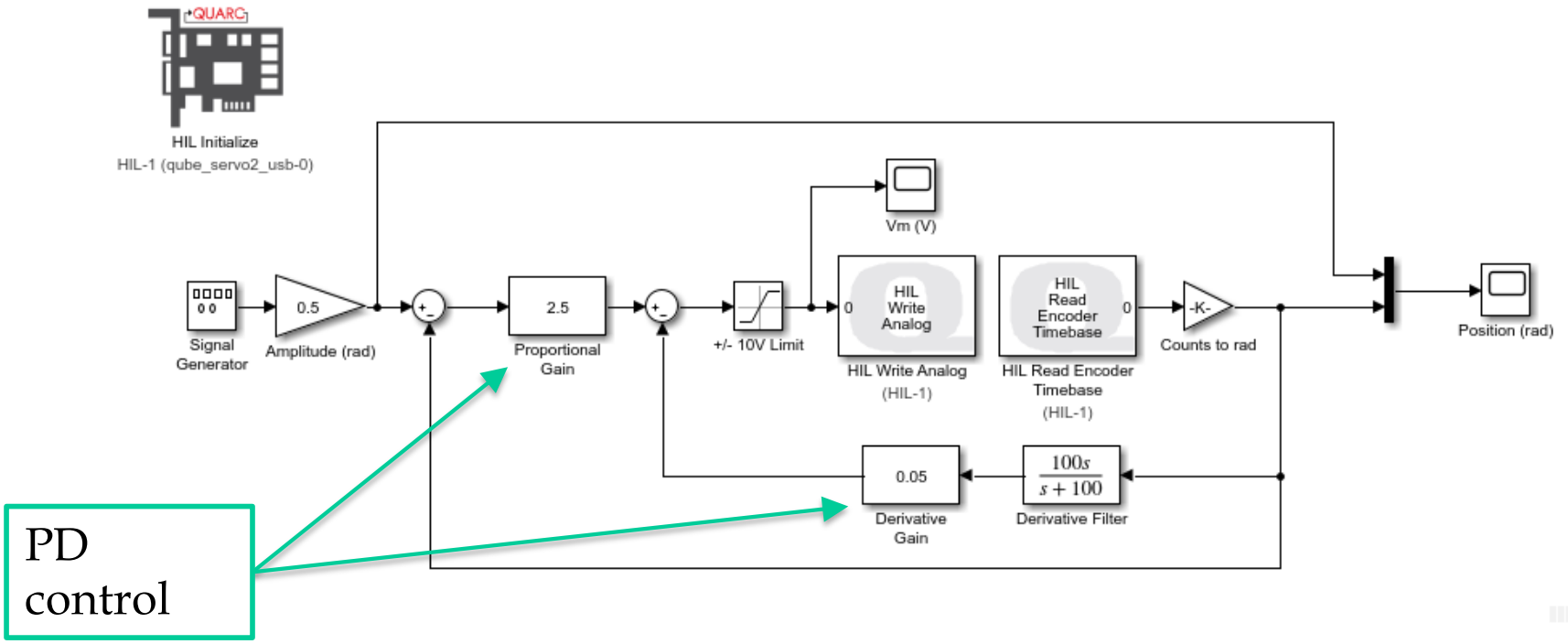




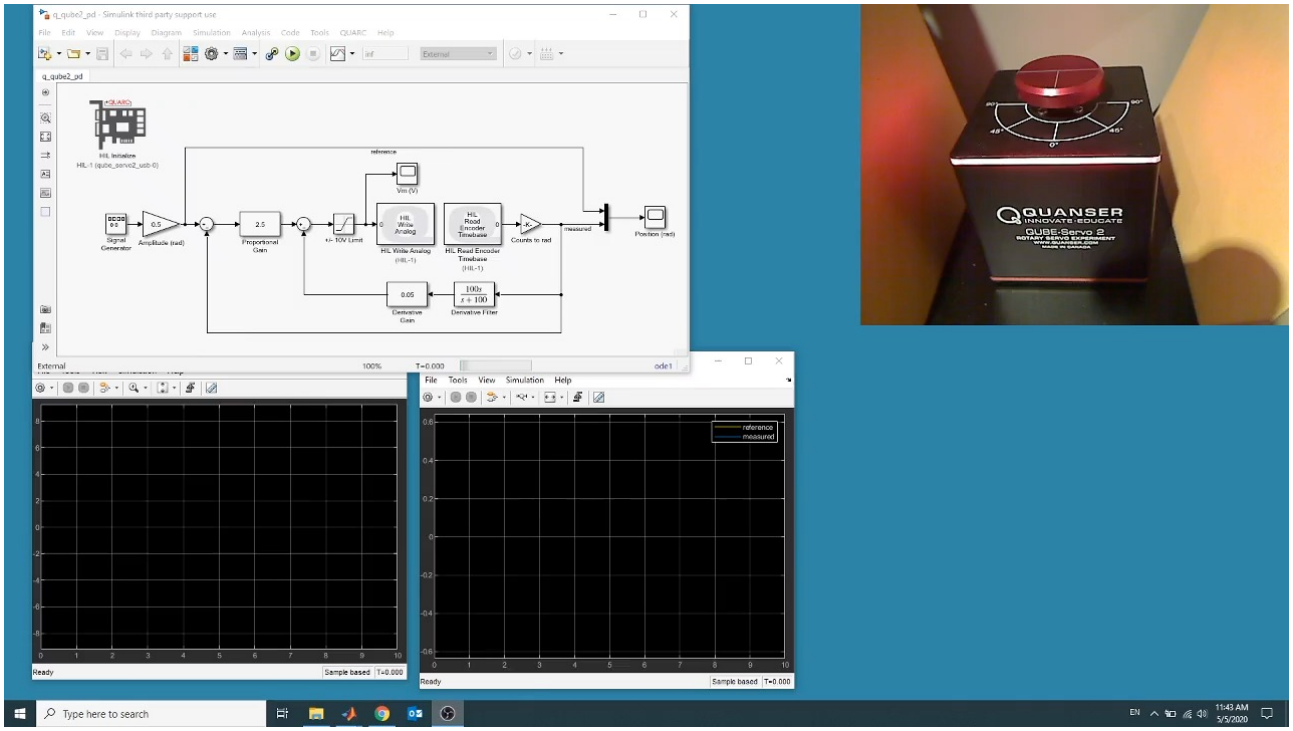
PD control of motor angular position



PD control implementation



PD control of motor angular position



Lab 2 - State-feedback control of QUBE rotary inverted pendulum

Modeling

State-Space Modeling

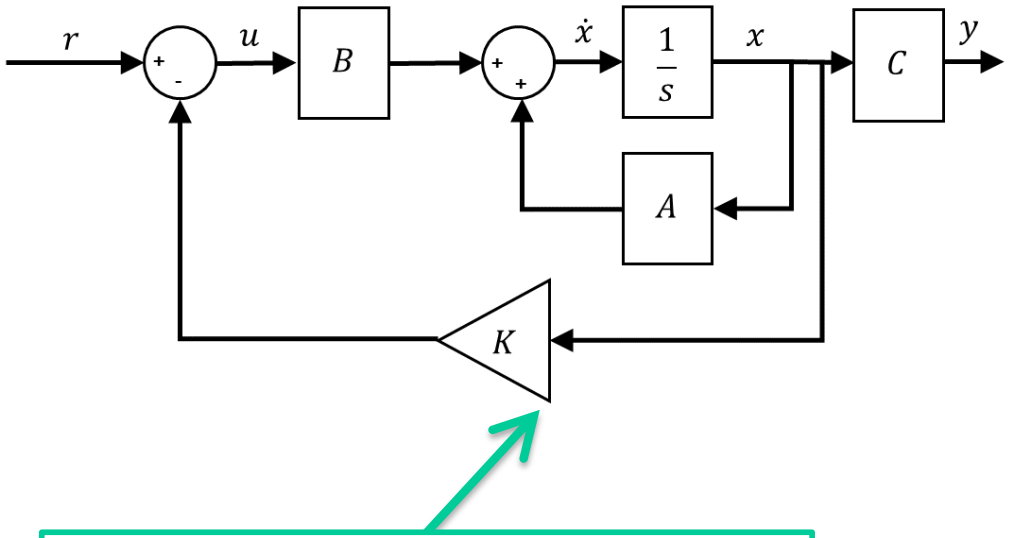
from physic laws

Control Design

LQR balance control

Swing-up control

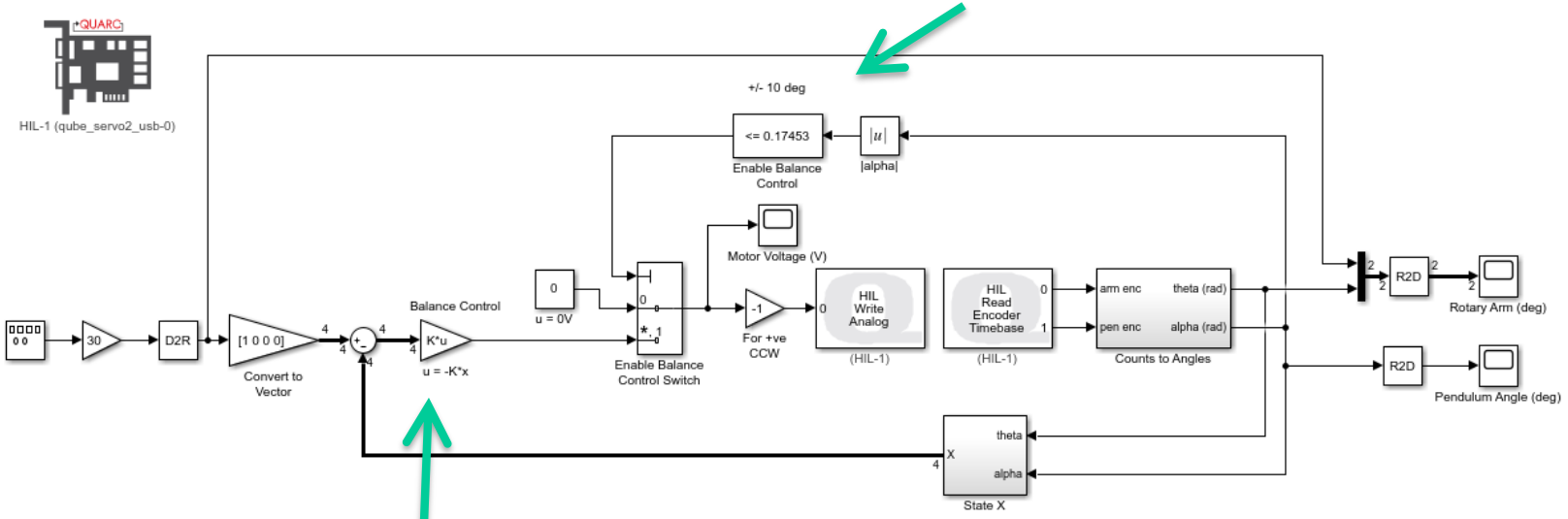
State-feedback LQR control of the inverted pendulum



Use state-feedback LQR control to balance pendulum

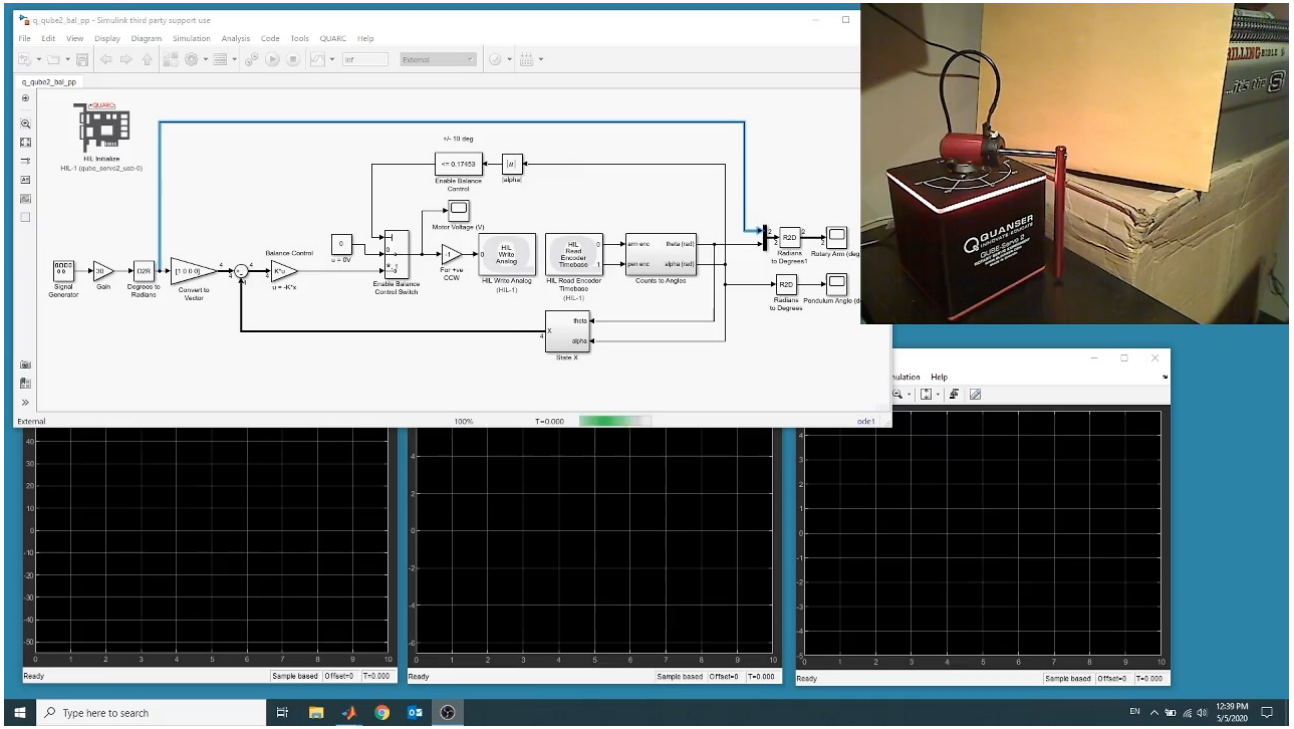
LQR control implementation

Engage when +/- 10 deg about vertical



State-feedback control

Optimal LQR-based balance control



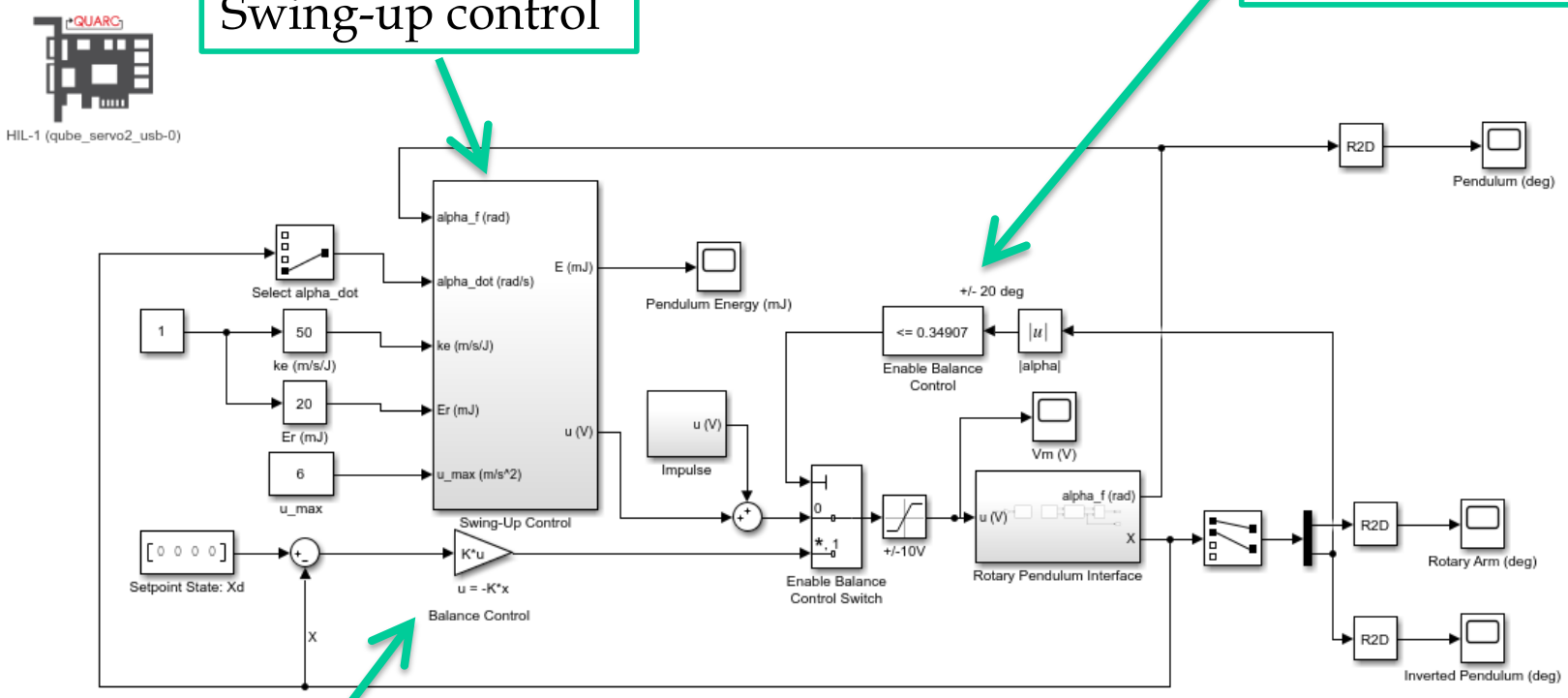
Pendulum swing-up by nonlinear energy control

- Swinging up a pendulum can be done analytically using a **nonlinear control**

Pendulum swing-up + balance implementation

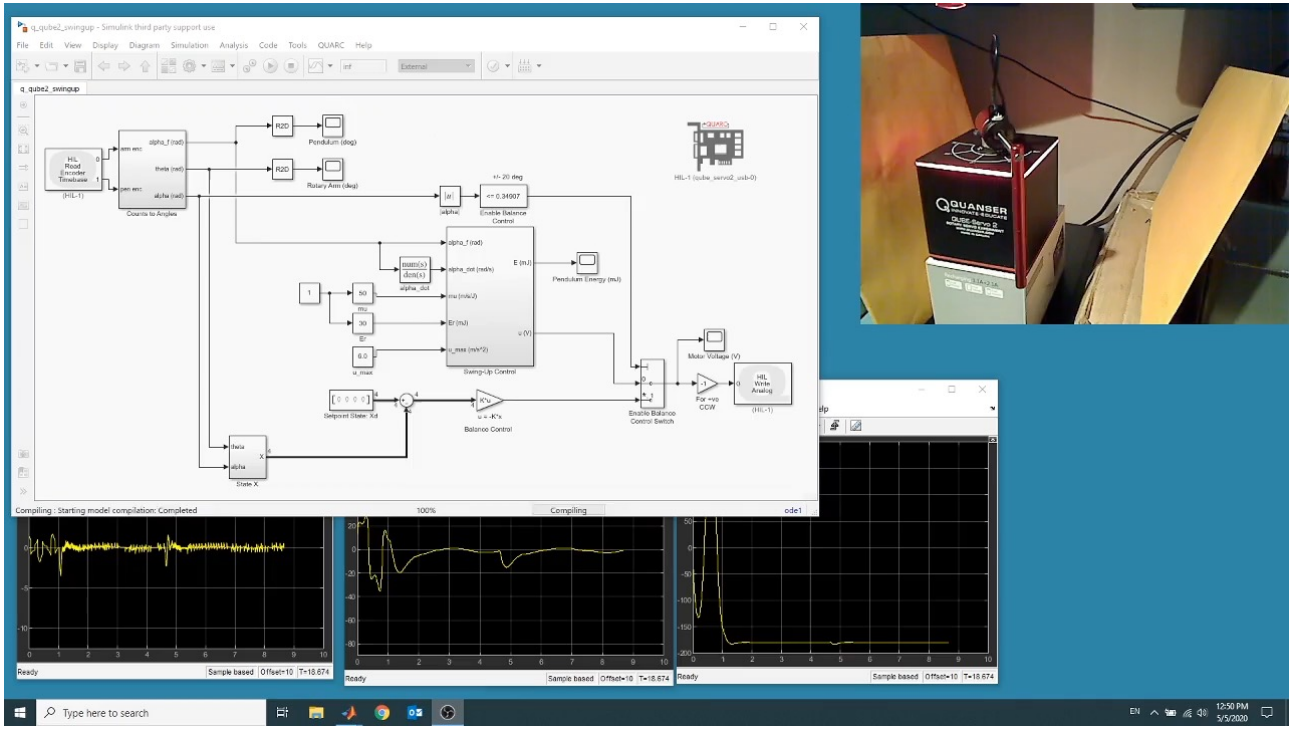
Switch to balance model when +/- 20 deg

Swing-up control



State-feedback balance control

Swing-up and balance control of the QUBE Servo-2 inverted pendulum

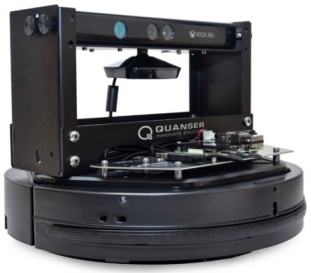


Lab 2 - Image–based control of the Ball & Beam with the QUBE-Servo 2

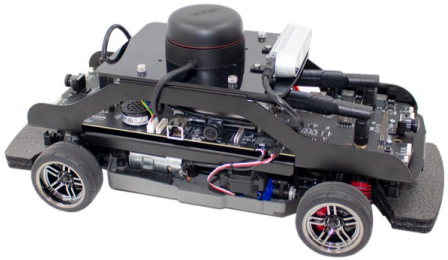
Balance control of two QUBE-servo 2

Mobile robots used during the remaining 6 labs

The Qbot



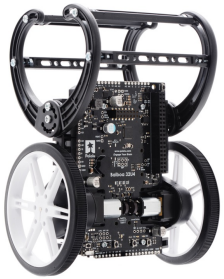
The Qcar



The 3pi+

The Tello drone

The Balboa



The Zumo