Bioprocessing Modeling and Simulation with MATLAB

Hands-on Workshop

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Agenda

- Industry Applications of MATLAB and Simulink

- Hands-On Exercises
  - Day 1 – Reaction Kinetics and Bioreactors
  - Day 2 – Parameter Estimation and Bioreactor Optimization

- Learning Resources

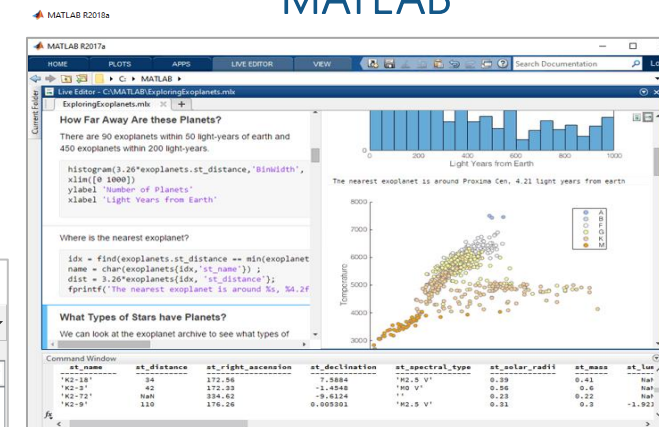# Our Products

MATLAB

&SIMULINK®

- MATLAB is a programming environment for algorithm development, data analysis, visualization, and numeric computation.

- Simulink is a graphical environment for designing, simulating, and testing systems.

- 100 add-on products for specialized tasks.
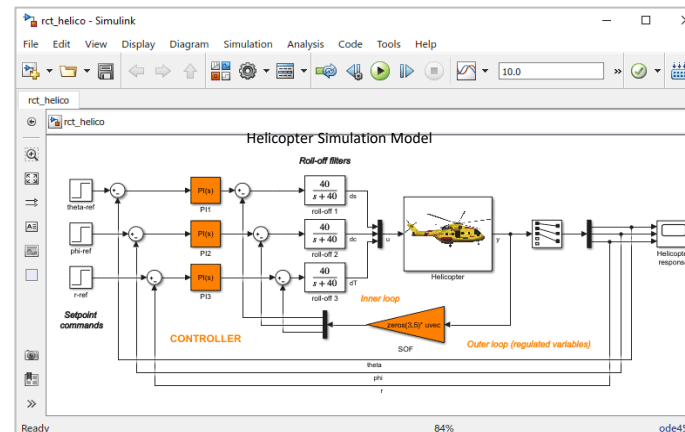
MATLAB

Simulink

Application Areas of MATLAB and Simulink

Aerospace

Automotive

Biological Sciences

Biotech and Pharmaceutical

Electronics

Energy production

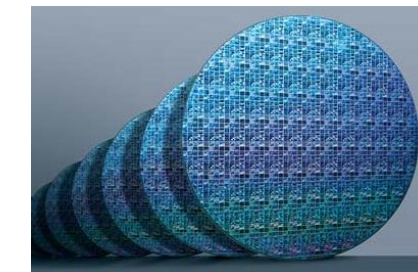**Financial Services**

Industrial Machinery
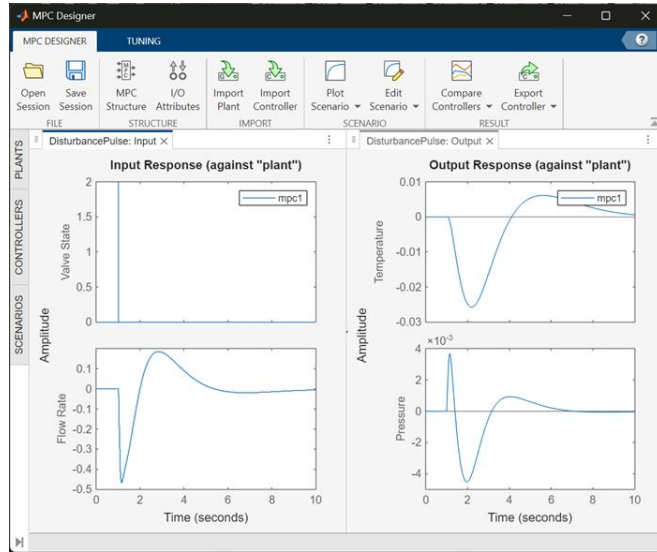

Process Industries

Neuroscience

Medical Devices

Semiconductors

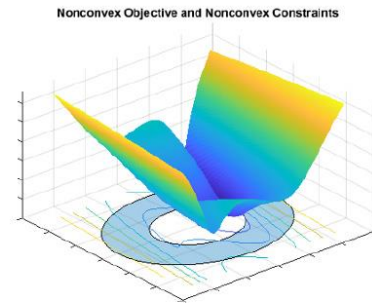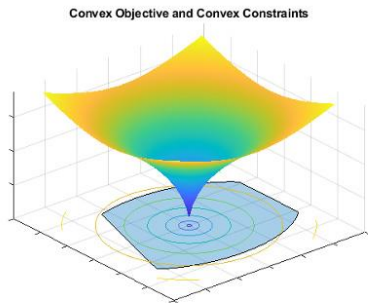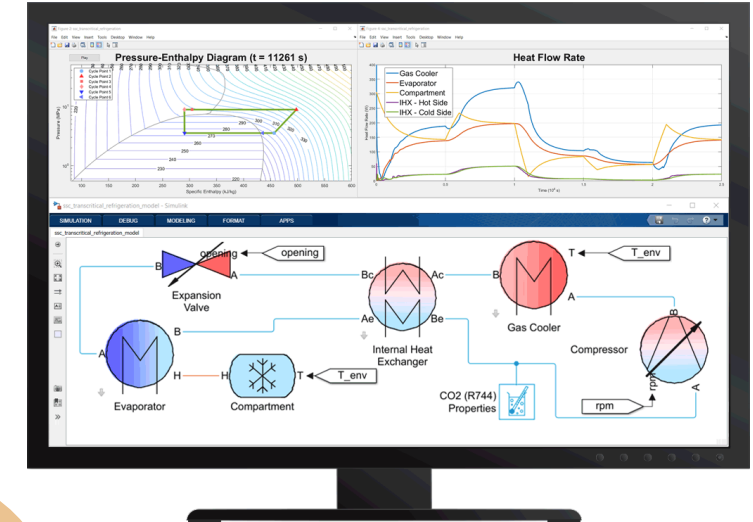# When you think of chemical processes, you think of..

Process Design

Process Control

Heat Exchangers
Reactors Pumps
Compressors
Absorption/Stripping Columns
Distillation Columns
Vessels

Process Safety & Environmental Impacts

Process Optimization

Convex Objective and Convex Constraints

Nonconvex Objective and Nonconvex Constraints

HUGO PETERSEN Models Industrial Chemical Processes with MATLAB and Simulink

Challenge
Accelerate development of industrial chemical processing plants

Solution
Use Model-Based Design with MATLAB and Simulink to simplify and automate the design workflow

Results
- Development time reduced by a factor of 5 to 10
- System behavior verified via simulation, reducing risks at plant startup time
- Flexible designs, enabling a quick response to changing customer requirements
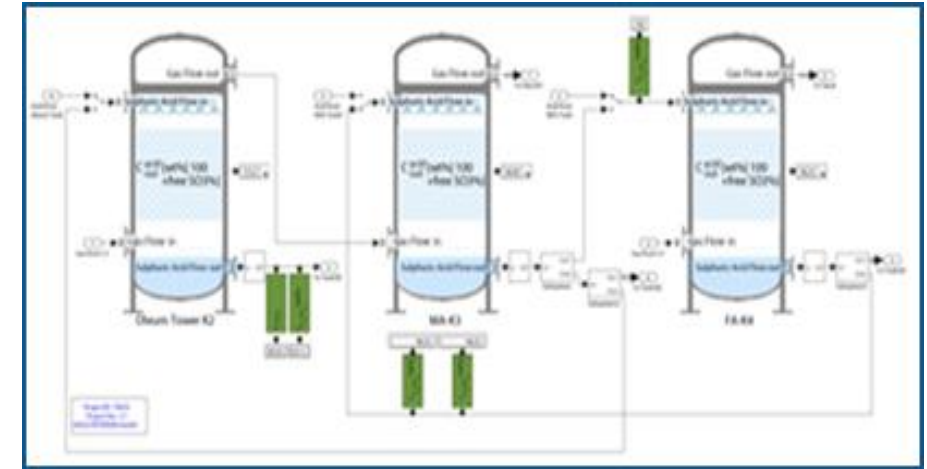
An absorption unit for a sulfuric acid plant modeled in Simulink.

"Overall, MATLAB and Simulink have enabled us to cut costs and reduce development time by a factor of 5 to 10. We have designed and simulated systems—including the largest oleum plant in the world—that were far too complex to handle with our spreadsheet-based approach."

- Ahmad Fani Yazdi, HUGO PETERSEN GmbH

Link to article

Genentech Uses MATLAB and Industrial Communication Toolbox to Build a Supervisory Control Algorithm Development Platform for Bioreactors
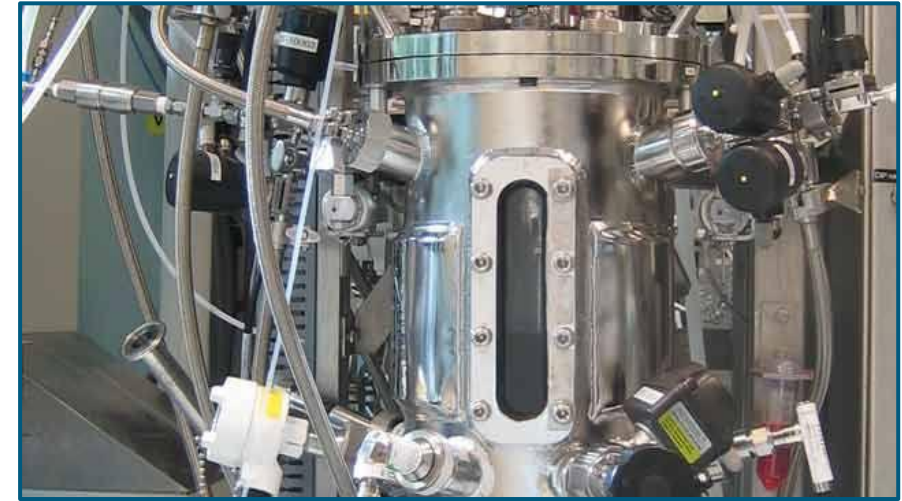
Challenge

Accelerate the development of control algorithms for microbial fermentations

Solution

Use MATLAB and Industrial Communication Toolbox to develop a continuous-uptime supervisory control platform that enables rapid development, debugging, and verification of algorithms

A Genentech microbial pilot plant bioreactor.

Results

- **Algorithm development time cut from months to weeks**
- Flexible, reliable infrastructure deployed
- Potential errors identified in minutes

"By partnering with MathWorks Consulting, we developed a robust platform for supervisory control with MATLAB and transitioned our pilot plant to a modern automation control system. This enabled our researchers to rapidly take algorithms from idea to implementation, simulation, and deployment."

- Dr. Ryan Hamilton, Genentech

Link to user story

University of the Witwatersrand Engineering Students Monitor, Visualize, and Analyze Experiment Data Virtually

Challenge

Offer real-world education experience in chemical process control when not everyone has access to a lab.

Solution

Upload data in real time to ThingSpeak to allow students and collaborators to monitor, visualize, and analyze it, and import data into MATLAB for further analysis.

Key Outcomes

- Researchers gained the ability to run experiments—in this case optimizing the fermentation of bioethanol—from afar.
- Combined and observed data in real time and shared it with others who have browser access.
- The system was especially useful in South Africa, where universities lack resources and face rolling blackouts that shut down university servers.

The microbrewery plant at the University of the Witwatersrand, showing the fermentation vessel on the right. (Image credit: Antony Higginson)

"What [ThingSpeak] gives you is an ability to prototype very quickly and have something that's going to collect all your data and share it with collaborators."
— Antony Higginson, University of the Witwatersrand

Mitsubishi Tanabe Pharma Develops Data Analysis Tools to Speed Drug Discovery

Challenge

Improve the drug candidate selection process by streamlining data analysis in drug metabolism, pharmacokinetics, and other studies

Solution

Use MATLAB to develop algorithms for quantitatively analyzing images and video, and work with MathWorks consultants to create standalone analysis applications for deployment to bench scientists

Results

- Algorithms developed four times faster
- Simultaneous analysis of multiple drugs enabled, with analysis times cut by 75%
- Deployment workload reduced by 83%
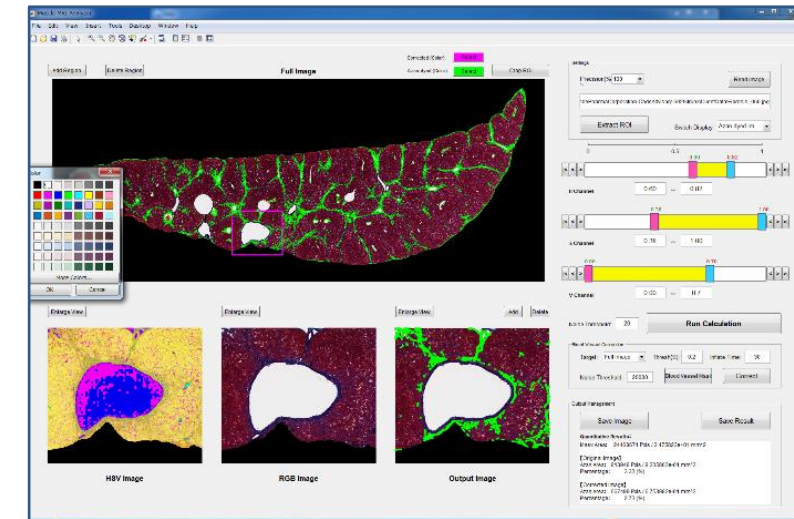
A pathological analysis tool based on MATLAB developed by Mitsubishi Tanabe Pharma.

"The algorithms we developed in MATLAB and deployed as applications with help from MathWorks consultants have enabled us to obtain quantitative analysis results, avoid human error, collaborate more effectively, reproduce results reliably, and double the number of feasibility studies completed yearly."

- Ryuta Saito, Mitsubishi Tanabe Pharma

Link to user story

Hands-On Workshop

- Please copy or download the exercise files from MATLAB Drive link:

  https://drive.mathworks.com/sharing/4cc50cd7-a3b9-46e5-96c1-944bd41eb1b7

- Workshop License Links:

Online : https://www.mathworks.com/licensecenter/classroom/4824301/

Desktop : https://www.mathworks.com/licensecenter/classroom/4824302/

Workshop Exercises – Day 1

Files:

- Bioreactor_Day1_Exercise.mlx (open this for hands-on practice)
- Bioreactor_Day1_Solution.mlx (use this if you get stuck)

Learning Objectives:

- Symbolically manipulating reaction kinetics equations with Symbolic Math Toolbox
- Solving ODEs to model bioreactors (batch, CSTR) and visualizing results
- Solving ODEs programmatically and interactively using MATLAB

Workshop Exercises – Day 2

Files:

- Bioreactor_Day2_Exercise.mlx (open this for hands-on practice)
- Bioreactor_Day2_Solution.mlx (use this if you get stuck)

Learning Objectives:

- Optimizing bioreactors using Global Optimization Toolbox
- Using Curve Fitting Toolbox for Reaction Kinetics Parameter Estimation
- Using Optimization Toolbox for Reaction Kinetics Parameter Estimation
- Defining and solving optimization problems programmatically and interactively

Resources

- [Batch Process Optimization with MATLAB](#)

- [Chemical Engineering Webinar Series 2023](#)
  (Chemical Kinetics and Reaction Engineering with MATLAB)

- [Reaction Kinetics with MATLAB](#)

- [Elements of Chemical Reaction Engineering](#)

MathWorks Tools for Reaction Kinetics & Reactor Modeling and Optimization:

[MATLAB](#)	[Optimization Toolbox](#)
[Global Optimization Toolbox](#)	[Curve Fitting Toolbox](#)
[Symbolic Math Toolbox](#)	[SimBiology](#)
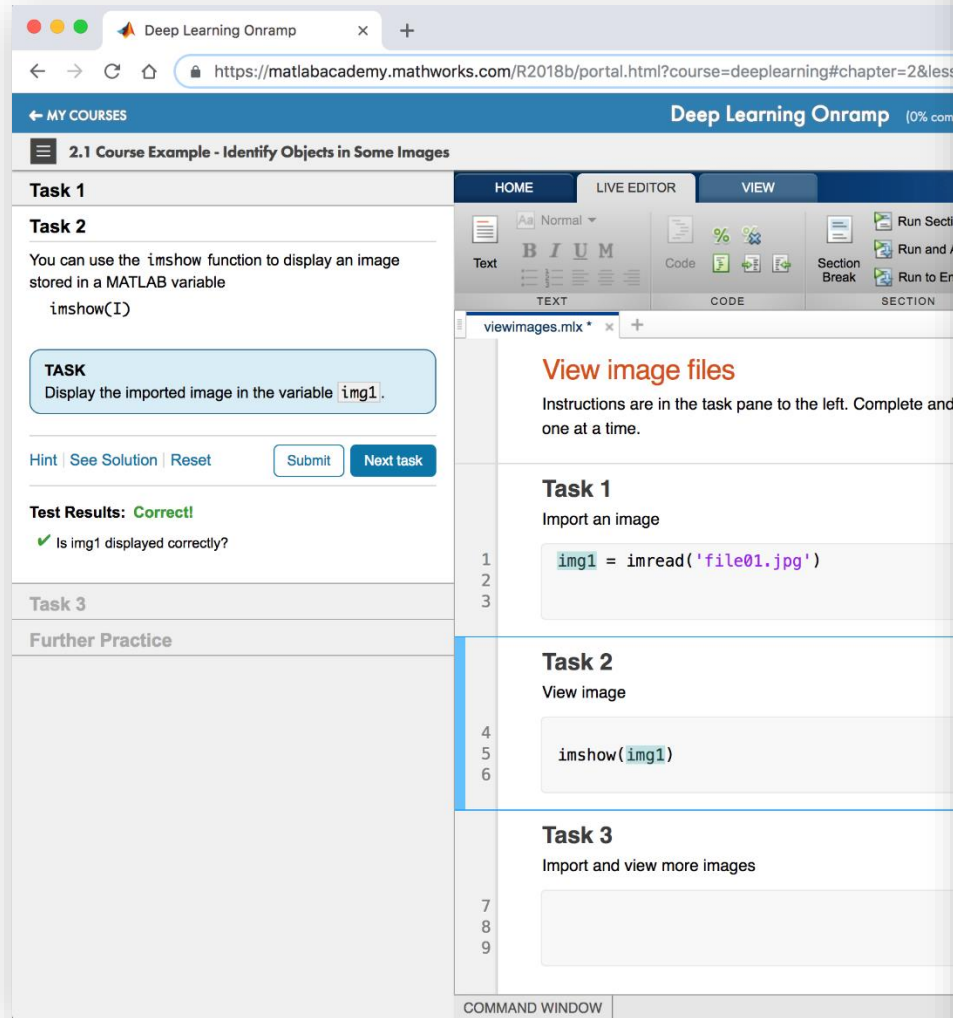
Online Training Courses

https://matlabacademy.mathworks.com/

Modular Courseware by MathWorks
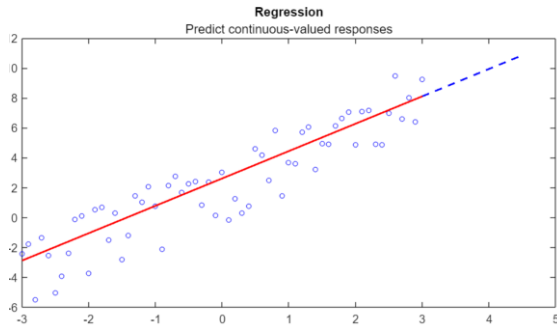
Machine Learning for Regression
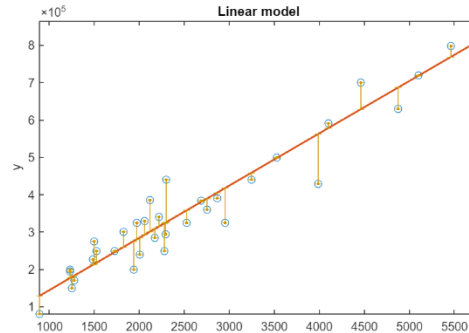
Regression Basics

Machine Learning Methods – Clustering

Modular Courseware by Educators
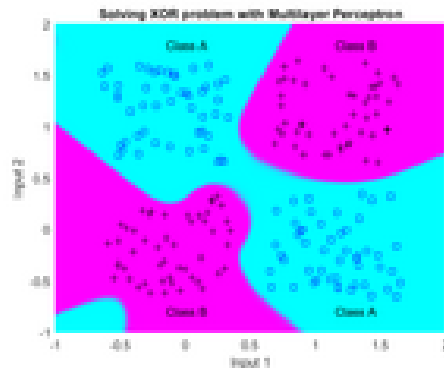
Fundamentals of Neural Networks

Machine Learning for Engineers

Check out the material from "AI and Predictive Maintenance in Chemical Engineering" Webinars!

Scan for Recordings

https://content.mathworks.com/viewer/65e0def6336fa2640b9c0664

Challenge your students with projects related to industry trends

- Projects on [Monitoring and Control of a Bioreactor](#) and [more](#)

- Do you have project ideas? [Share](#) with us!

- Learn more about [MathWorks Challenge Projects Program](#)
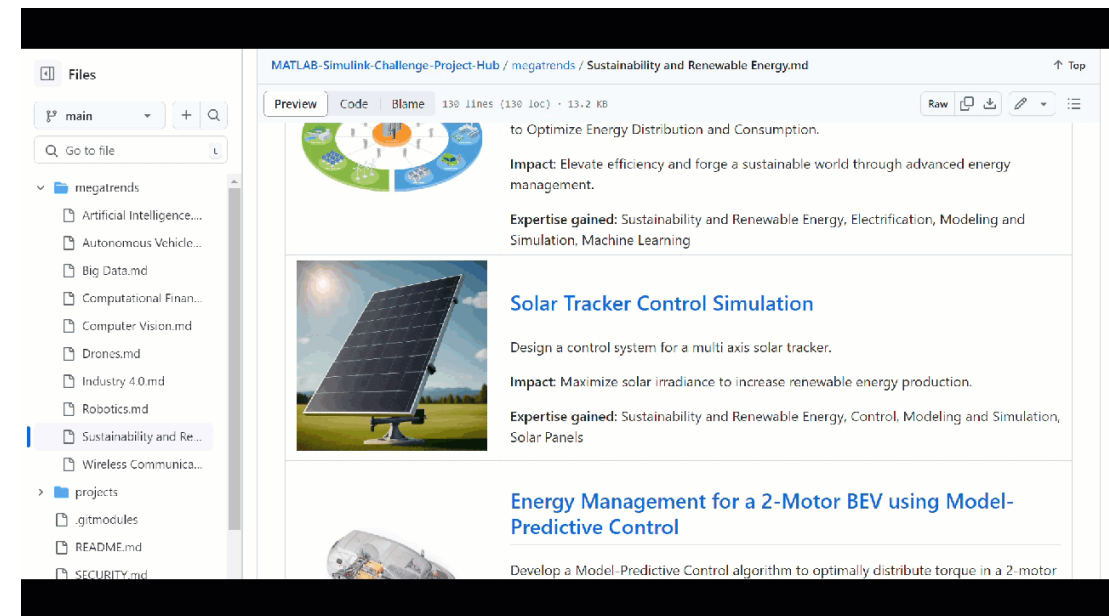
Resources for Chemical Engineering Courses