

# Bioprocessing Modeling and Simulation with MATLAB

## Hands-on Workshop

Aycan Hacıoglu, Ph.D. – Academic Discipline Manager, Chemical Engineering

[ahaciogl@mathworks.com](mailto:ahaciogl@mathworks.com)

Tharrini Raj – Customer Success Engineer

[tharaj@mathworks.com](mailto:tharaj@mathworks.com)

# Agenda

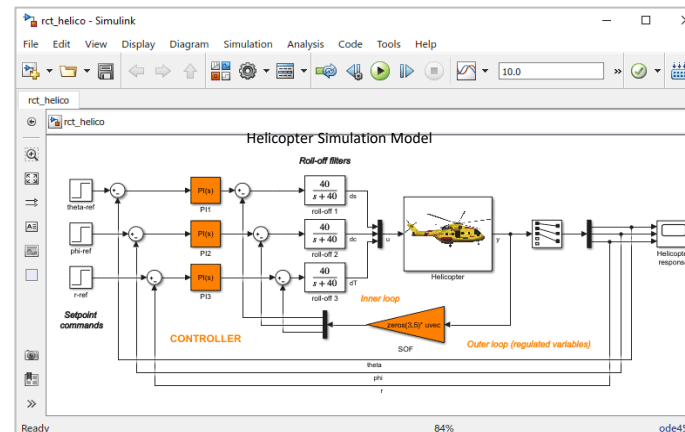
- Industry Applications of MATLAB and Simulink
- Hands-On Exercises
  - Day 1 – Reaction Kinetics and Bioreactors
  - Day 2 – Parameter Estimation and Bioreactor Optimization
- Learning Resources

# Our Products MATLAB® & SIMULINK®

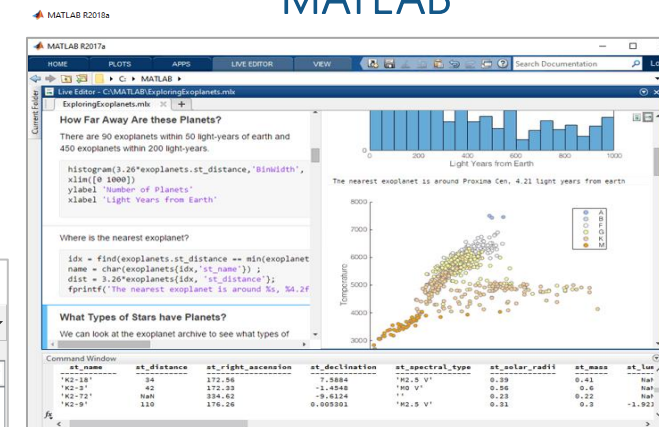


- MATLAB is a programming environment for algorithm development, data analysis, visualization, and numeric computation.
- Simulink is a graphical environment for designing, simulating, and testing systems.
- 100 add-on products for specialized tasks.

Simulink



MATLAB





# Application Areas of MATLAB and Simulink



**Aerospace**



**Automotive**



**Biological Sciences**



**Biotech and Pharmaceutical**



**Electronics**



**Energy production**



**Financial Services**



**Industrial Machinery**



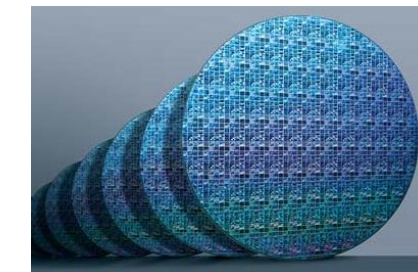
**Process Industries**



**Neuroscience**

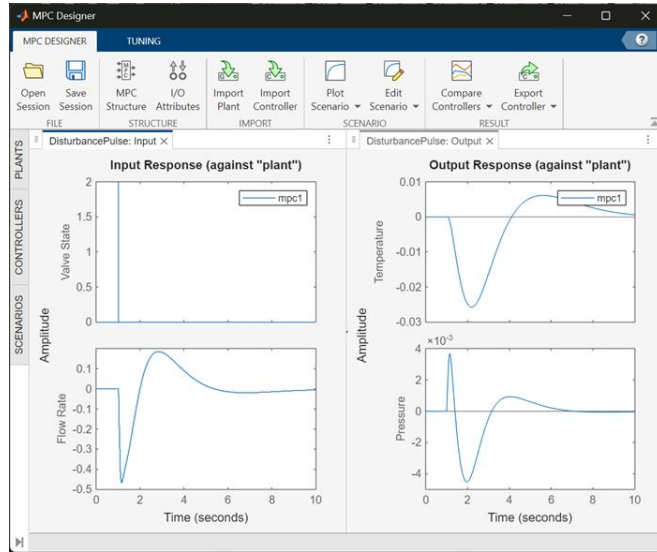


**Medical Devices**



**Semiconductors**

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



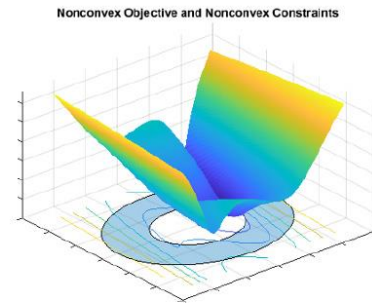
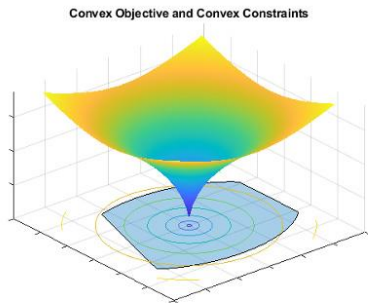
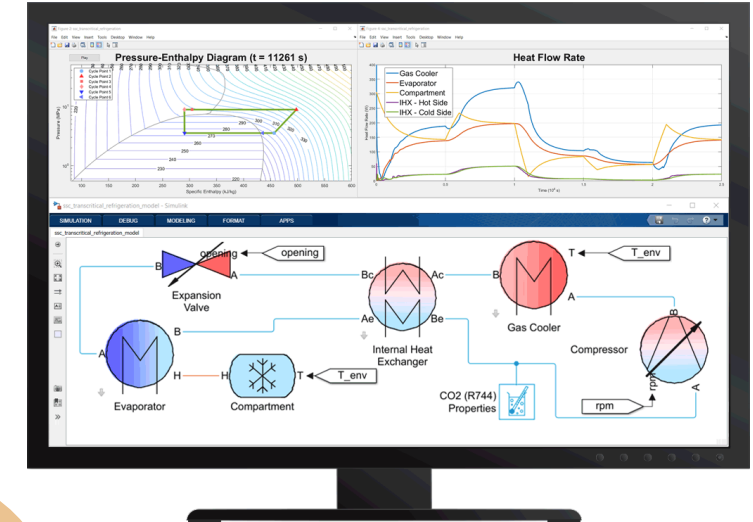
Process Design

Process Control

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

Process Safety & Environmental Impacts

Process Optimization



# HUGO PETERSEN Models Industrial Chemical Processes with MATLAB and Simulink

## Challenge

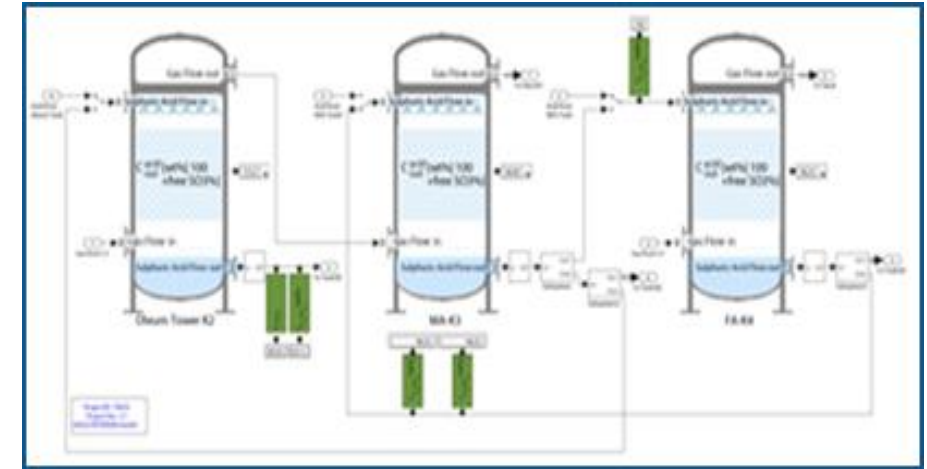
Accelerate development of industrial chemical processing plants

## 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*



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

## Challenge

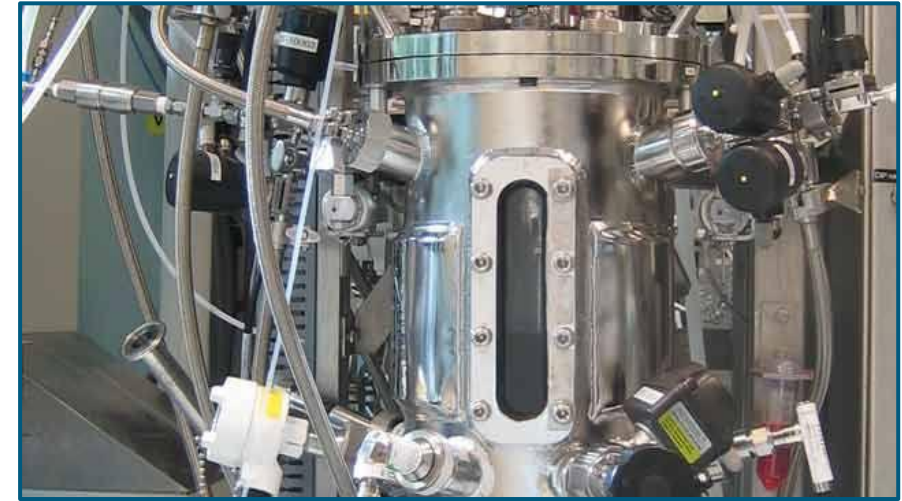
Accelerate the development of control algorithms for microbial fermentations

## Solution

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

## Results

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



A Genentech microbial pilot plant bioreactor.

*“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*

# 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

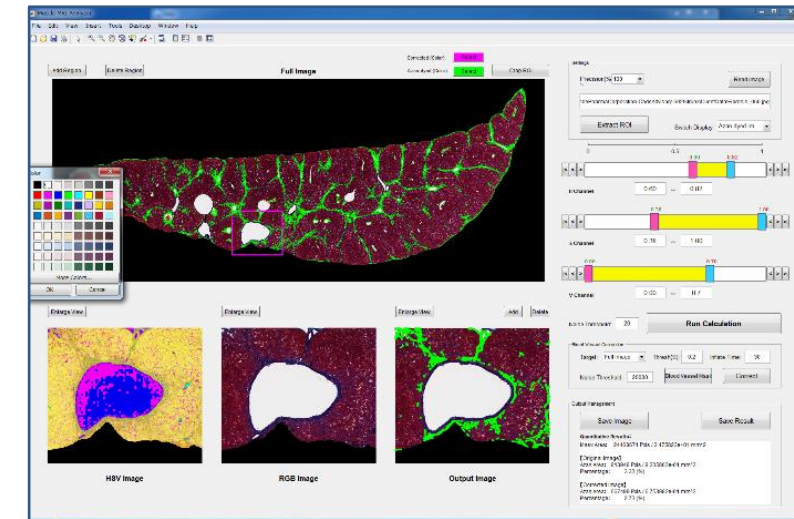
Improve the drug candidate selection process by streamlining data analysis in drug metabolism, pharmacokinetics, and other studies

## 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*

# 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](#)

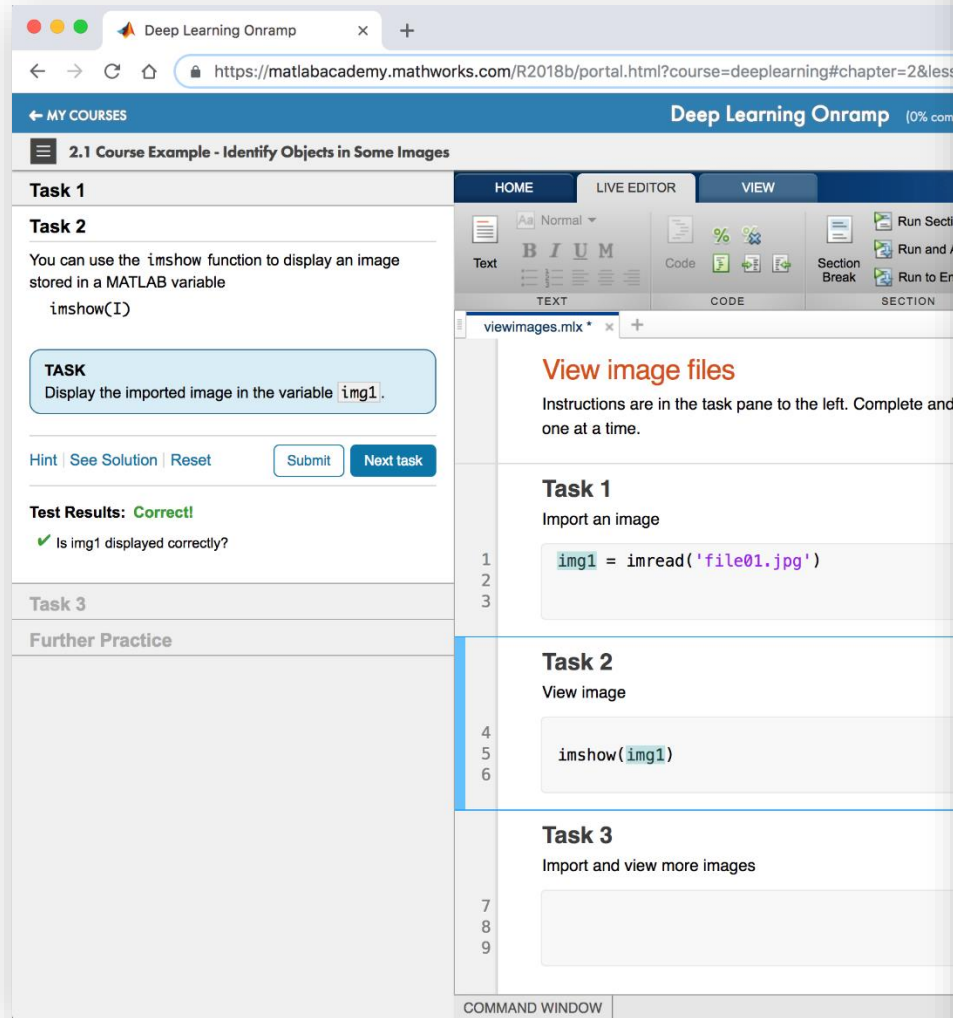
[Curve Fitting Toolbox](#)

[Symbolic Math Toolbox](#)

[SimBiology](#)

# Online Training Courses

<https://matlabacademy.mathworks.com/>



Deep Learning Onramp

2.1 Course Example - Identify Objects in Some Images

**Task 2**

You can use the `imshow` function to display an image stored in a MATLAB variable `img1`.

`imshow(I)`

**TASK**

Display the imported image in the variable `img1`.

Hint | See Solution | Reset

Submit Next task

**Test Results: Correct!**

✓ Is `img1` displayed correctly?

**Task 3**

Further Practice

viewimages.mlx

**View image files**

Instructions are in the task pane to the left. Complete and one at a time.

**Task 1**

Import an image

```
img1 = imread('file01.jpg')
```

**Task 2**

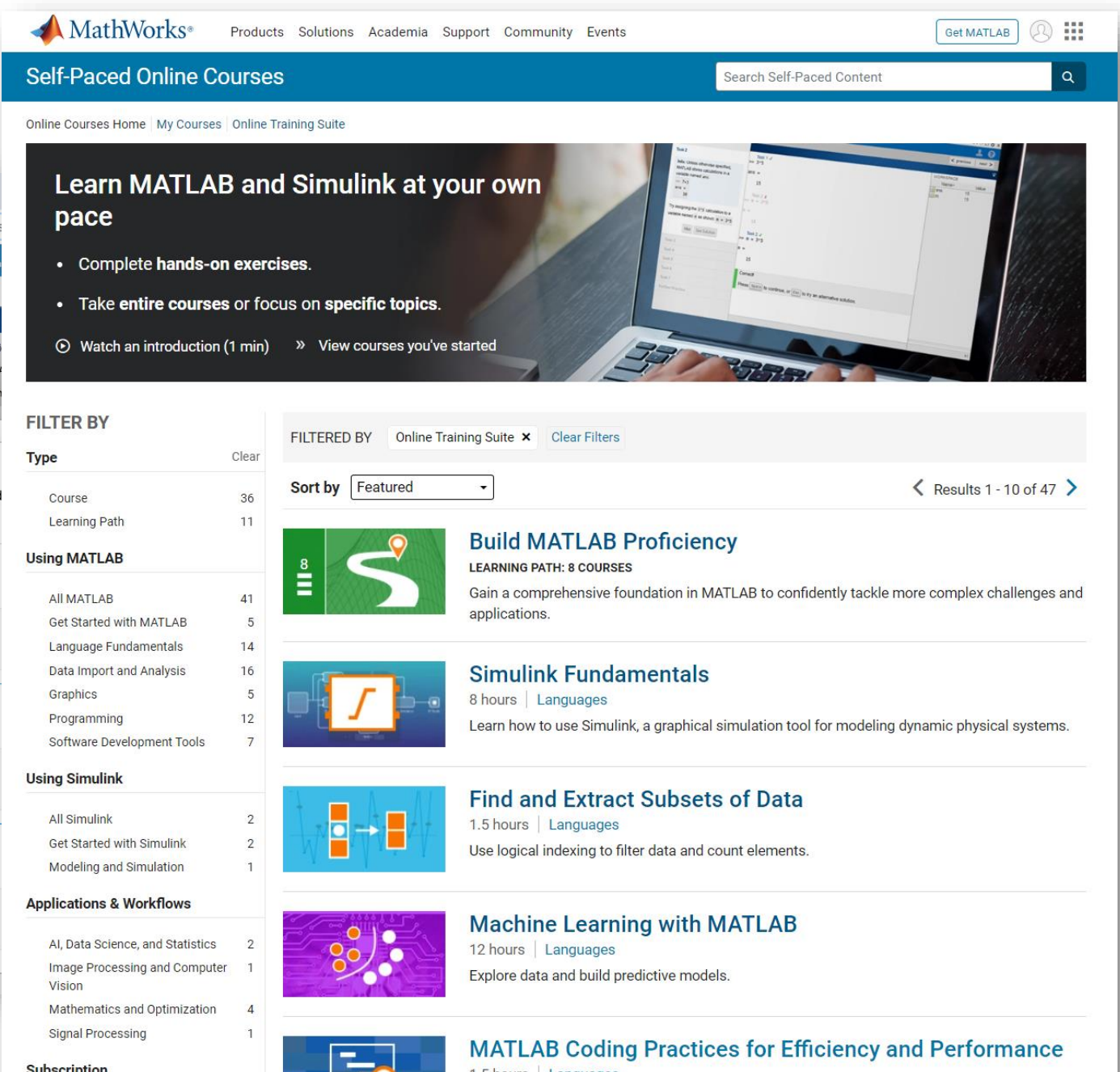
View image

```
imshow(img1)
```

**Task 3**

Import and view more images

COMMAND WINDOW



MathWorks® Products Solutions Academia Support Community Events

Get MATLAB

Self-Paced Online Courses

Search Self-Paced Content

Online Courses Home | My Courses | Online Training Suite

**Learn MATLAB and Simulink at your own pace**

- Complete hands-on exercises.
- Take entire courses or focus on specific topics.

Watch an introduction (1 min) » View courses you've started

**FILTER BY**

Type	Count
Course	36
Learning Path	11

**Using MATLAB**

All MATLAB	41
Get Started with MATLAB	5
Language Fundamentals	14
Data Import and Analysis	16
Graphics	5
Programming	12
Software Development Tools	7

**Using Simulink**

All Simulink	2
Get Started with Simulink	2
Modeling and Simulation	1

**Applications & Workflows**

AI, Data Science, and Statistics	2
Image Processing and Computer Vision	1
Mathematics and Optimization	4
Signal Processing	1

**Subscription**

**Built MATLAB Proficiency**

LEARNING PATH: 8 COURSES

Gain a comprehensive foundation in MATLAB to confidently tackle more complex challenges and applications.

**Simulink Fundamentals**

8 hours | Languages

Learn how to use Simulink, a graphical simulation tool for modeling dynamic physical systems.

**Find and Extract Subsets of Data**

1.5 hours | Languages

Use logical indexing to filter data and count elements.

**Machine Learning with MATLAB**

12 hours | Languages

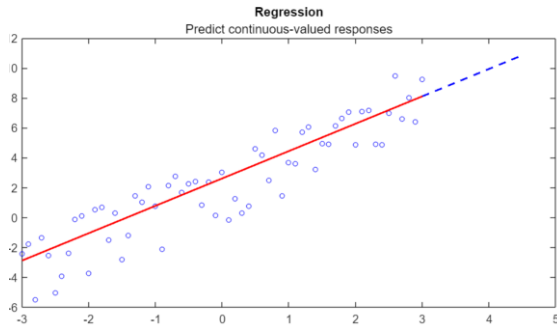
Explore data and build predictive models.

**MATLAB Coding Practices for Efficiency and Performance**

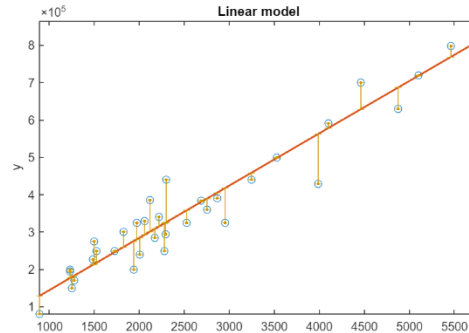
1.5 hours | Languages



# Modular Courseware by MathWorks



[Machine Learning for Regression](#)

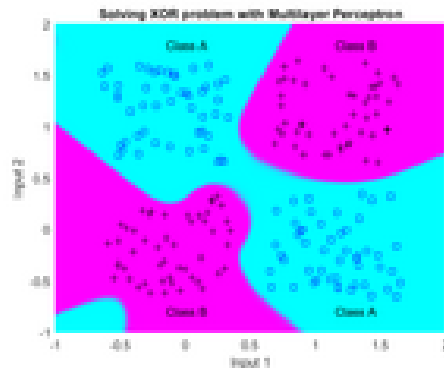


[Regression Basics](#)



[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!

[Get MATLAB](#)

## MATLAB and Simulink Seminars

### AI and Predictive Maintenance in Chemical Engineering Webinar Series

#### Overview

Artificial Intelligence (AI) is revolutionizing engineering across all disciplines, necessitating that engineers adeptly weave AI into their practices. This webinar series targets chemical engineering, offering insights into machine learning, deep learning, and predictive maintenance using MathWorks tools.

#### Highlights

- Cutting-edge applications of AI and predictive maintenance in both chemical engineering research and industry practices.
- An overview of end-to-end machine learning, deep learning, and predictive maintenance solutions with MathWorks tools
- MATLAB-based curriculum resources designed to seamlessly blend AI into the chemical engineering courses

We highly recommend these free sessions to chemical engineering students, faculty, industry professionals, and anyone with an interest in the subject matter. No prior knowledge of MATLAB or Simulink is necessary to participate.



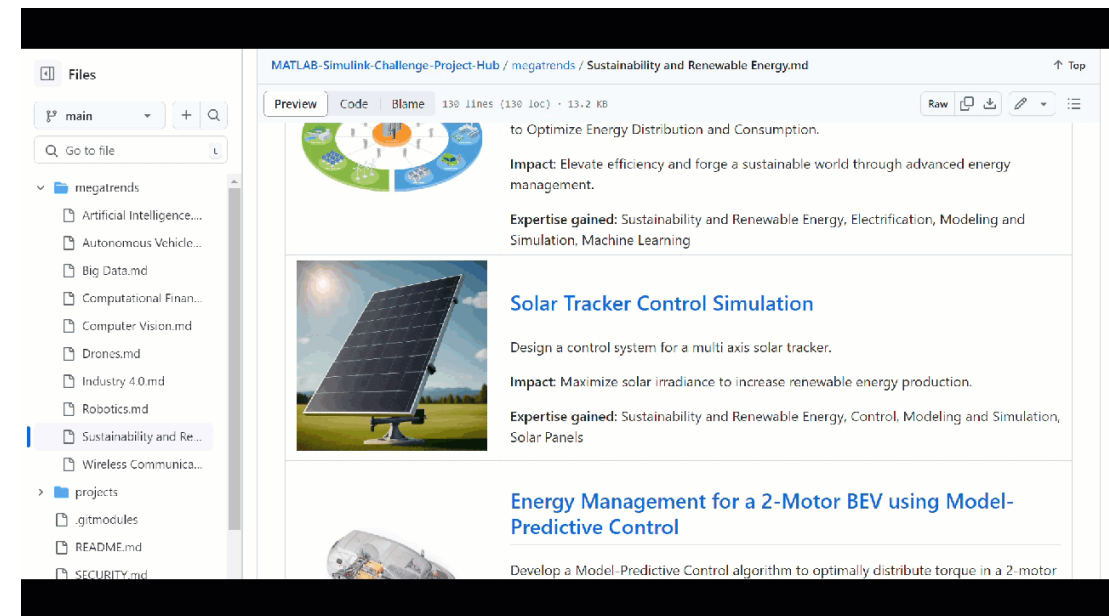
Scan for Recordings



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

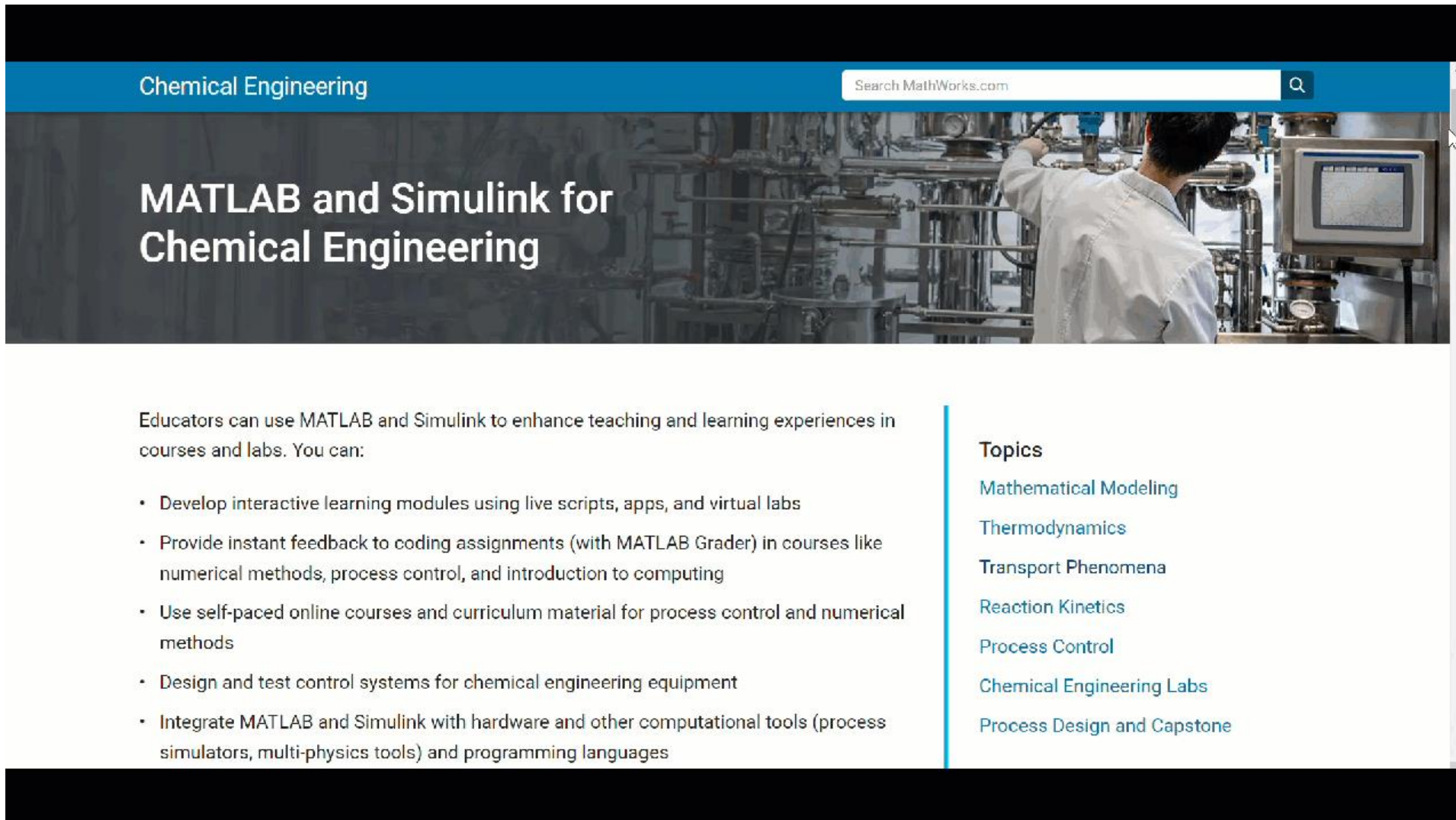
# Challenge your students with projects related to industry trends

- 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



Chemical Engineering

Search MathWorks.com

## MATLAB and Simulink for Chemical Engineering

Educators can use MATLAB and Simulink to enhance teaching and learning experiences in courses and labs. You can:

- Develop interactive learning modules using live scripts, apps, and virtual labs
- Provide instant feedback to coding assignments (with MATLAB Grader) in courses like numerical methods, process control, and introduction to computing
- Use self-paced online courses and curriculum material for process control and numerical methods
- Design and test control systems for chemical engineering equipment
- Integrate MATLAB and Simulink with hardware and other computational tools (process simulators, multi-physics tools) and programming languages

### Topics

- Mathematical Modeling
- Thermodynamics
- Transport Phenomena
- Reaction Kinetics
- Process Control
- Chemical Engineering Labs
- Process Design and Capstone