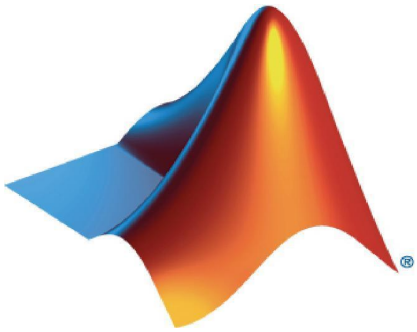
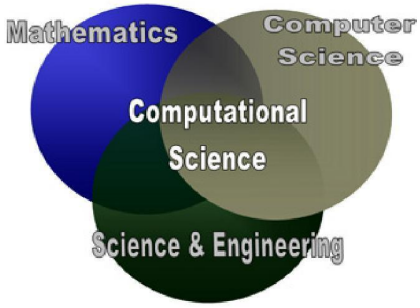
# CME 292: Advanced MATLAB for Scientific Computing

**Schedule**: Winter 2021, Jan 3rd-Jan 26th, Mon/Wed 5:30 - 7:00pm
**Room**: Remote (Zoom link will be available through Canvas) for the first two weeks; In Lathrop Library, Rm 299 for the last two weeks.
**Units**: 1






## Course Description

The goal of this 8-lecture short course is to introduce advanced MATLAB features, syntaxes, and toolboxes not traditionally found in introductory courses; applications will be drawn from various topics from scientific computing. Material will be reinforced with in-class examples and demos involving topics from scientific computing. Students will be practicing the knowledge learned through a mini course project, which will be based on either the suggested topics or a topic of their own choice. MATLAB topics to be covered will be drawn from: advanced graphics and animation, MATLAB tools, data management, code optimization, object-oriented programming, and a variety of toolboxes, including optimization, statistical and machine learning, deep learning, parallel computing, and symbolic math. Students should expect to gain exposure to the tools available in the MATLAB software, knowledge of and experience with advanced MATLAB features, and independence as a MATLAB user. Successful completion of the course requires completion of a mini project.

## Prerequisites

CME 192 (Introduction to MATLAB) or equivalent programming background in other languages is highly recommended prior to taking this course.
Basic knowledge of numerical analysis and numerical linear algebra is recommended.

## Course Outline

| Lecture | Topic | Date | Dues |
|---|---|---|---|
| 1 | MATLAB Fundamentals<br>• Data types and Structures<br>• Table and Timetable<br>• Function and Function Handle | 1/3 Mon (Zoom) | |
| 2 | Graphics and Data Visualization<br>Efficient Code Writing:<br>• Publishing Code | 1/5 Wed (Zoom) | |

| | | | |
|---|---|---|---|
| | • Code Debugger and Analyzer<br>• Profiler<br>• Code Performance<br>• Parallel Processing | | |
| **3** | File Manipulation<br>Big Data Handling | 1/10 Mon (Zoom) | Project Topic & Team Sign-Up due at the beginning of Lecture 3 |
| **4** | Applied Math with MATLAB<br>• Numerical Linear Algebra<br>• Optimization<br>• Symbolic Math<br>• ODE and PDE | 1/12 Wed (Zoom) | Project Statement (1~2 paragraphs) due at 1/14 Fri midnight of Week 2 |
| **5** | Machine Learning<br>• Statistics and Machine Learning Toolbox<br>• Deep Learning Toolbox | 1/17 Mon (Lathrop) | |
| **6** | Advanced Programming<br>• Object Oriented Programing<br>• Interactivity with Other Languages | 1/19 Wed (Lathrop) | |
| **7** | Other Advanced Tools<br>• Image Processing Toolbox and Computer Vision Toolbox<br>• Signal Processing Toolbox and Audio Toolbox | 1/24 Mon (Lathrop) | Project Report Draft (2~4 pages) due at the beginning of Lecture 7 |
| **8** | Project Presentation | 1/26 Wed (Lathrop) | Project Presentation due at Lecture 8<br>Project Report (3~4 pages) Due at the end of Week 4 (1/30 Sun midnight) |

## Instructor

Xiran Liu, Ph.D. Candidate, Institute of Computational and Mathematical Engineering
Bass Biology Research Building, Room 236, 327 Campus Drive
Email: xiranliu@stanford.edu
Office Hours: by appointment (can set up regular hours if there is interest)

## Mini Project

The goal of the mini project is to let you get involved in some practices of the topics covered in class and get some hands-on experience using advanced MATLAB features. It is not intended to be time-consuming or requiring much prior knowledge of advanced MATLAB.

**Choice of Topic**:
There are two options we provide:

1. We provide a list of suggested topics (attached below). You may pick one from the list. Note that some of the examples involve tools we do not cover in class but may be of interest for people with specific application fields in mind. We provide the link(s) to examples that use advanced MATLAB features and/or tools, and we want you to either

- apply the similar techniques onto some other data of interest, or
- go through similar procedures to model a system, build an interface, create a simulation, etc.

The specific problem chosen should be of similar or higher level of complexity compared to the examples.

2. If you have some specific tasks of interest that you think can be done by MATLAB, using features and/or tools at or above the level of those we introduce in this class, you may also choose to do your mini project on that. Some examples are:
    - analysis of some dataset you use in your own research
    - modeling some dynamic system you are studying

You may work on the project individually, or in a group of 2. **The team formation and topic choice are due by Lecture 3.** Feedback on the project choices will be provided by Lecture 4, and changes can be made accordingly if needed. *If you join the course late, please contact the instructor to catch up on the process.*

**Project Statement**:
The 1-page project statement is due on the Friday of the second week. It should contain one to two paragraphs including the following information:

1. Background: introduce the background of the problem you choose to work with
2. Introduction to Data/Model: briefly describe the dataset you will use, or the system you want to model, or the animation/interactive app you want to build, etc.

**Project Report**:
The project report should extend the content of your problem statement to include:

3. **Methodology**: explain the method you use to tackle the problem
4. **Results**: show the outcomes of your analysis or modeling, with a few sentences describing your findings. We encourage you to include advanced visualization(s) of your results using MATLAB graphics features. If you work with an animation or interactive app, you may choose to include a few screenshots of your product and demo it live during the presentation.
5. **Discussion/Conclusion**: comment on your work, for example, challenges encountered, interesting findings, limitations, potential future directions, etc.

Each of these can be a few paragraphs, plus the figures and tables. The project report should be at least 3~4 pages long in total (including the statement). Feel free to have longer reports if you make a lot of progress.

You can write the report either in word, latex, or MATLAB live script, and hand it in as a **pdf file**. Note that we *do not want you to include code* in your report. If you have to do that, put the code in the appendix. If you choose to write in live script, we encourage you to put most of your code in separate files and just call those files from your main script, so that *your main scripts will consist mainly of texts and figures*.

A *draft* is due at the beginning of the 7$^{th}$ lecture. This is intended to check-in on your progress. The *final version* of the report is due at the end of Week 4.

**Project Presentation**:
The presentation is scheduled at the last lecture. Each group (1-2 people) will give a 5-10 minute presentation, followed by a few minutes of Q&A. The time is subject to change upon the enrollment of the class. Please prepare a few slides to introduce your project, including the methods and the results. If you work with animations/interactive apps, please include live demos in your presentation.

Here we provide a list of suggested project topics, together with the examples.

**Suggested topics**:

| | Topic | Example | Link | Project Ideas |
|---|---|---|---|---|
| 1 | PageRank | PageRank Algorithm to Rank Websites | www.mathworks.com/help/matlab/math/use-page-rank-algorithm-to-rank-websites.html | Analyze some network dataset of interest using PageRank and provide advanced visualizations. |
| 2 | Spatial Data Analysis | Map Creation Using Latitude and Longitude Data | www.mathworks.com/help/matlab/creating_plots/plot-in-geographic-coordinates.html | Perform analysis on some spatial (and temporal) dataset of interest and provide advanced visualizations. |
| | | Density of Cellular Tower Placement | www.mathworks.com/help/matlab/creating_plots/view-density-of-cellular-tower-placement.html | |
| | | Cyclone Track Data in Geographic Density Plot | www.mathworks.com/help/matlab/creating_plots/view-cyclone-track-data-in-geographic-density-plot.html | |
| | | Create Geographic Bubble Chart from Tabular Data | www.mathworks.com/help/matlab/creating_plots/create-geographic-bubble-chart-from-tabular-data.html | |
| 3 | Animation | Animation of Graphics Object | www.mathworks.com/help/matlab/creating_plots/animate-graphics-object.html | Create an animation for some system of interest, and possibly include interactive functionality. |
| | | Animating a Surface | www.mathworks.com/help/matlab/creating_plots/animating-a-surface.html | |
| 4 | Interactive App | App: Using Multiple Axes to Display Results of Image Analysis | www.mathworks.com/help/matlab/creating_guis/image-histogram-gui-in-app-designer.html | Create an interactive app for analysis or visualization of some dataset or system of interest. |
| | | App: Sorting and Editing Table Interactively | www.mathworks.com/help/matlab/creating_guis/interactive-table-gui-in-app-designer.html | |
| 5 | Computational Biology | Identifying Differentially Expressed Genes from RNA-Seq Data | www.mathworks.com/help/bioinfo/ug/identifying-differentially-expressed-genes-from-rna-seq-data.html | Choose some biological or biomedical dataset of interest and use Bioinformatics Toolbox to analyze data. |
| | | Exploring Genome-wide Differences in DNA Methylation Profiles | www.mathworks.com/help/bioinfo/ug/exploring-genome-wide-differences-in-dna-methylation-profiles.html | |
| | | Gene Expression Profile Analysis | www.mathworks.com/help/bioinfo/ug/gene-expression-profile-analysis.html | |
| | | Analyzing the Origin of the Human Immunodeficiency Virus | www.mathworks.com/help/bioinfo/ug/analyzing-the-origin-of | |

| | | | | |
|---|---|---|---|---|
| | | | -the-human-immunodeficiency-virus.html | |
| 6 | Classical Machine Learning | Statistical and Machine Learning | www.mathworks.com/help/stats/examples.html?category=index&exampleproduct=all&s_tid=CRUX_lftnav | Explore the use of machine learning algorithms on a problem of interest using the Statistical and Machine Learning Toolbox. |
| 7 | Deep Learning | Deep Learning | www.mathworks.com/help/deeplearning/examples.html?category=index&exampleproduct=all&s_tid=CRUX_lftnav | Explore the use of deep learning models on a problem of interest using the Deep Learning Toolbox. |
| 8 | Computer Vision | Computer Vision Examples | www.mathworks.com/help/vision/examples.html?category=index&exampleproduct=all&s_tid=CRUX_lftnav | Perform computer visions tasks on some image or video dataset of interest using the Computer Vision Toolbox. |
| 9 | Finance | Portfolio Optimization Examples | www.mathworks.com/help/finance/portfolio-optimization-examples.html | Explore portfolio optimization based on market data, potentially using the Financial Toolbox. |
| 10 | Optimization | Optimization | www.mathworks.com/help/optim/examples.html?category=index&exampleproduct=all&s_tid=CRUX_lftnav | Solve some optimization problems using the Optimization Toolbox. |
| 11 | PDE | PDE | www.mathworks.com/help/pde/examples.html?category=index&exampleproduct=all&s_tid=CRUX_lftnav | Solve a PDE system of interest using the Partial Differential Equation Toolbox. |

* If you want to do a data-oriented mini project and do not have any dataset in mind, there are plenty of open-source datasets online (e.g., Datasets suggested by MATLAB for deep learning applications https://www.mathworks.com/help/deeplearning/ug/data-sets-for-deep-learning.html, Kaggle datasets www.kaggle.com/datasets). There are also many blog plots of where to find good datasets (e.g., www.v7labs.com/blog/best-free-datasets-for-machine-learning). Feel free to reach out to the instructor if you have trouble finding an interesting dataset.