# COMPUTATIONAL METHODS FOR BIOENGINEERS

***Mon/Wed, Section 001, 11:50 – 1:10, WEB L124***
***Mon/Wed, Section 002, 3:00 – 4:20, WEB L124***
***Tues/Thurs, Section 003, 9:10 – 10:30, WEB L124***

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Location: MEB 2475

Assistant: Dylan Blair
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Assistant: David Jiang
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Hours: Tuesdays 1:15 – 2:45
Location: WEB 2626

## *Course Overview*

Computers are increasingly indispensable in biomedical engineering research for data acquisition, analysis and modeling. For students who have not received appreciable programming training, this course covers basic computation skills including data representation, storage, display, descriptive statistics, numerical analysis theory, optimization, and other relevant topics via hands-on exercises based on real biomedical engineering applications. A high-level multi-purpose scientific computing package (MATLAB) is used. Adequate progress in computational understanding and in MATLAB programming techniques is essential to other courses that you will take or may be taking concurrently.

## *Recommended Course Materials*

MATLAB for Engineers, Holly Moore, 4th Edition
MATLAB Student Version. In the bookstore or online at www.mathworks.com.

## *Grades*

Homework 35%
Exam 25%
Project 25%
Quizzes 10%
Project Participation 5%

***Class Time***

Attendance during regularly scheduled classes is expected. In addition to regular classes, the teaching assistants will conduct open lab hours. Students are welcome to attend any open lab sessions.

***Homework***

Homework will be assigned nearly every class and will be due on the day of the next class. Homework must be turned in via digital upload to Canvas on the day it is due. (11:59pm MST). Homework will not be accepted in any form other than digitally uploaded to Canvas.

> **Uploading your solutions 00 – 12 hours late will result in a 20% deduction.**
> **Uploading your solutions 12 – 24 hours late will result in a 40% deduction.**
> **Uploading your solutions 24 – 36 hours late will result in a 60% deduction.**
> **Uploading your solutions 36 – 48 hours late will result in an 80% deduction.**
> **Homework will not be accepted 48 hours after it was due.**

When uploading your homework to Canvas, use the following naming convention:
LastnameFirstname_Homework#. (pdf, m, jpg, mat)
(e.g. EllisBen_HW01.m or SarangJoshi_HW03.mat)

In addition, the top line of any file submitted must include your name and date as a comment:

*% Code by Ben Ellis for BIOEN 3301 HW#, January 8, 2018*

You are encouraged to consult with others (including instructors, teaching assistants and students) to help with understanding and solving the homework and term project. You should ask questions and help each other figure out the path to the solutions. However, when it comes to actually writing your program and writing down the homework answers, you must do your own work. Each student submits individual homework solutions. **You must write your own code. Use of code written by anyone other than you will result in failing the class and potentially other administrative punishments.**

***Exam***

The exam is completely individual, and during an exam you must not give or get help from any other person. There will be one in-class, midterm exam covering topics from the homework and lectures. **No make-up exam or extra-credit will be given.** Any violations of this rule will be dealt with by strict College disciplinary policy (www.regulations.utah.edu/academics/6-400.html).

***Quizzes***

There will be five short multiple-choice quizzes. The main purpose of the quizzes is to help you practice for the multiple-choice portion of the exam. The quizzes, like the exam, are completely individual, and during the quizzes you must not give or get help from any other person. The quizzes will be closed-book and will cover topics from the recent homework and lectures. **No make-up quizzes or extra-credit will be given.** Any violations of this rule will be dealt with by strict College disciplinary policy (www.regulations.utah.edu/academics/6-400.html).

***Projects***

You and 2 to 3 team members will have a chance to apply numerical methods to a real-world bioengineering project of your choice. At the end of the semester, your team will turn in a paper describing the problem and your solution (along with your MATLAB code), and will give an oral presentation to the class.

***Schedule***

| Day | Date | Topic | Readings | Assignments Due |
|---|---|---|---|---|
| M,T | Jan 8,9 | Course Introductions & MATLAB Environment | Ch 1 | |
| W,Th | Jan 10,11 | Variables & Scripts | Ch 2 | |
| M,T | Jan 15,16 | ----- *No class: Martin Luther King Jr. Day* ----- | | |
| W,Th | Jan 17,18 | Commands | Ch. 3 | HW 1 |
| M,T | Jan 22,23 | Matrices | Ch. 4 | HW 2 |
| W,Th | Jan 24,25 | Plotting **(QUIZ)** | Ch. 5 | HW 3 |
| M,T | Jan 29,30 | Functions | Ch. 6 | HW 4 |
| W,Th | Jan 31, Feb 1 | Input & Output | Ch. 7 | HW 5, Project Teams |
| M,T | Feb 5,6 | Logical Functions & Selection Structures **(QUIZ)** | Ch. 8 | HW 6 |
| W,Th | Feb 7,8 | Logical Functions, Selection & Repetition Structures | Ch. 8 & 9 | HW 7 |
| M,T | Feb 12,13 | Repetition Structures | Ch. 9 | HW 8 |
| W,Th | Feb 14,15 | Data Structures **(QUIZ)** | Ch. 11 | HW 9 |
| M,T | Feb 19,20 | ----- *No class: President's Day* ----- | | |
| W,Th | Feb 21,22 | Matrix Operations | Ch. 10 | HW 10 |
| M,T | Feb 26,27 | Advanced Graphics | Ch. 14 | HW 11, Project Abstracts |
| W,Th | Feb 28, Mar 1 | Advanced Graphics **(QUIZ)** | Ch. 14 | HW 12 |
| M,T | Mar 5,6 | Numerical Techniques | Ch. 13 | |
| W,Th | Mar 7,8 | Numerical Techniques **(QUIZ)** | Ch. 13 | HW 13 |
| M,T | Mar 12,13 | Midterm Review | | |
| W,Th | Mar 14,15 | Midterm | | |
| M,T | Mar 19,20 | ----- *No class: Spring Break* ----- | | |
| W,Th | Mar 21,22 | ----- No class: Spring Break ----- | | |
| M,T | Mar 26,27 | Structure of computer programs | | Project Proposals |
| W,Th | Mar 28,29 | Graphical User Interfaces | | |
| M,T | Apr 2,3 | Graphical User Interfaces | | |
| W,Th | Apr 4,5 | Application: | | |
| M,T | Apr 9,10 | Project Time | | Project Alpha Release |
| W,Th | Apr 11,12 | Application: | | |
| M,T | Apr 16,17 | Project Time | | |
| W,Th | Apr 18,19 | Oral Project Presentations | | Project Beta Release |
| M,T | Apr 23,24 | Oral Project Presentations | | |
| W | May 2 | Final Project Papers Due by 5:00 PM | | Final Project |

***Note:*** *This schedule has been created as a guide to the class and is as accurate as possible. However, all information is subject to change as class needs change. Any changes will be discussed in advance during class sessions.*

***Project Details***

To explore the diversity of applications of MATLAB in bioengineering while demonstrating the student's MATLAB skills, students will undertake a programming project that meets the following criteria:

1) Projects are to be done in groups of three or four. All group members will provide equal

contributions to the project and will receive the same grade. If a lack of participation by any group member is observed, that person will receive a penalty as part of their 5% participation assessment for the class.

2) Topics of the projects need to be submitted via a written proposal and be approved by the instructor (see examples below).
3) Project topics should be chosen in consultation with any engineering or biomedical faculty member, and be aimed to analyze *real* experimental data (existing or to be acquired) from the faculty's lab.
4) The bulk of the projects should be *new* programming. A high degree of similarity with previous or existing MATLAB programs will result in a diminished or a zero grade.
5) Projects will be graded on the following 3 areas:
   a) Functionality*, 30% (program must work reliably)
   b) Difficulty*, 30% (nature of custom functions & complexity of algorithms)
   c) Presentation, 20% (including demonstration)
   d) Report, 20% (written report)

   * Functionality and Difficulty grades will depend on both the final product and the preliminary assignments, including: Proposal, Flowchart, and Alpha & Beta versions.

*Oral Reports*

Your report should be a PowerPoint and MATLAB presentation covering three parts:

1) Purpose and solution technique. Begin with information like title, team and sponsor names, and assigned tasks and collaboration within the group. Include an overview of the problem, significance, approach to the algorithm development, and justification of key formulas.
2) Real-time running and demonstration of MATLAB program. The purpose of the demonstration is to prove that you produced a solution for the problem you are addressing. This validates the completion of your project. The exact form of this demonstration will depend upon the nature of your project: some programs will analyze data, some will demonstrate a GUI, some will read and write files, some will plot, etc. Almost all will be executed as an m-file. However, it may be awkward for some programs to be demonstrated real-time in class within the time limit, so these projects should come up with some way to convince the class that the program works (simplified input data, intermediate output, or such).
3) Experience and conclusions. 2-3 slides describing the following parts of your conclusion: How well did the algorithm perform compared to built-in or "gold-standard" techniques? Do the results justify the methods used? What MATLAB capabilities did you learn from your project? More specifically, what obstacles did you have to overcome in programming beyond what you learned in class? How will your work benefit the sponsoring faculty's progress? How will the project help your future career endeavors?

**You may bring your own laptop to class, already loaded with your data, m-files, MATLAB and PowerPoint. Make sure ahead of time that your computer will work with the classroom projector. Alternatively, you may use the iMacs installed in the classroom. They do not have Powerpoint, but do have Open Office. Before presentation time, load your data and program on these machines. Your presentation will be a maximum of 20 minutes (a warning will be given at 18 minutes), with 3 minutes for questions and 2 minutes between groups.

*Written Reports*

The written report should be similar to a printed version of the oral presentation, but with an abstract, introduction, methods, results and discussion sections, and an appendix. The abstract should be a brief overview describing what you have done. The introduction should detail the importance of the problem including any relevant background information. The methods sections should focus on your design process and any algorithmic details hidden within the code. The results section should read like a user's manual for your program, and potentially include examples for users to try. Finally the discussion should mention strengths and weakness of your code and your approach, and what might be done with your code, or to improve your code, in the future. Include your code in the appendix. Members of the team will submit a single report and receive the same score.

**SAMPLE MATLAB PROJECT 1**

**Sponsoring faculty:** Edward Hsu

**Abstract:**
MRI encoding the translational diffusion of water molecules is called diffusion-weighted MRI. The technique can be used to detect acute stroke or to determine the orientation of tissue fibers (via anisotropic diffusion). Quantitative diffusion-weighted MRI requires the acquisition of series of MR images with varying degrees of diffusion-weighting. Due to instrumentation imperfections, diffusion-weighted images often suffer from distortion. To correct for the distortion, we will implement an image registration algorithm to determine the affine transformations (shift, shear and scaling) needed to deform a diffusion-weighted MR image such that it has the maximum similarity to a non-diffusion-weighted (undistorted) image.

**Basic Approach:**
1. Apply incremental affine deformations to the distorted image
2. Quantify the similarity between the deformed image and the undistorted reference image. Because diffusion-weighted and unweighted images have different image contrasts, we will use mutual information as the similarity metric.
3. Perform a multi-dimensional optimization such that the similarity metric under Step 1 is maximized.
4. Demonstrate that quantitative diffusion MRI can be improved by the distortion correction.

**Level of Difficulty:** High, from implementation of mutual information and multi-dimensional optimization.

**SAMPLE MATLAB PROJECT 2**

**Sponsoring faculty:** Edward Hsu

**Abstract:**
Tissue fiber orientations on histological slides are usually measured manually. To increase the processing speed and measurement objectivity, we will implement an automatic technique based on Fourier analysis.

**Basic Approach:**
1. Subdivide the scanned histological image into square regions of interest.
2. Compute the Fourier transform of the image and use linear regression to determine the axis of symmetry of the Fourier image.
3. Repeat 1 and 2 on a moving-window basis.
4. Provide an assessment of accuracy.

**Level of Difficulty:** Moderate. Most commands/functions needed already exist in MATLAB. This project could be made more difficult by implementing and comparing to an alternative technique (e.g. image gradient) of fiber orientation measurement.

**TERM PROJECT PROPOSAL TEMPLATE**

**Student Names:** _____
**Sponsoring Faculty:** _____
**Tentative Title of Project:** _____

**Overview of Project:**
What real-world bioengineering problem will this project address? Why is it an important problem? How can a computational method help solve the problem? Is the anticipated level of effort appropriate for a term project?

**Computational Approach:**
What capability of MATLAB will be applied to the problem? What built-in or user-defined functions will be needed? What input and/or output capabilities will be utilized? What will be the user interface? Will plotting or printing be done? Will data be generated? What is the estimated length of the program?

**Potential Difficulties:**
What are some potential difficulties that may arise as you pursue the project? How might you overcome these?

**Outcome of Project:**
What will be the "deliverable" to the sponsor (i.e., plots, statistics, data, values, images, understanding, etc.)?