I. Essential Information for Students during the First Meeting

42-699: Computational Methods in Biomedical Engineering (12 Units)

Instructor(s): Gustavo K. Rohde

Teaching Assistant: Soheil Kolouri (skolouri@andrew.cmu.edu)

Pre-requisite: calculus, multivariate calculus,

Classes:
- Mondays & Wednesdays, 9:00-10:20am.
- GHC 4211

Instructor Office Hours: Mondays 10:30-11:30 HH C 122
TA Office Hours: TBA

Description:

This goal of this course is to enable students with little or no programming background to solve common computational problems in biomedical sciences and engineering. Matlab programming will be covered, together with basic principles of computer architecture and arithmetic. Basic numerical techniques in numerical differentiation, integration, linear algebra, differential equations, and statistics, are covered and applied to quantitative analysis (mechanics, transport, reactions, etc.) of molecular systems, cells, and organs as well as studying aspects bioinstrumentation (e.g. data analysis). Coursework will consist of homework assignments, quizzes, and a final exam. Homework will consist of analysis exercises combined with programming assignments. Undergraduate engineering students at the junior and senior levels, as well as entry level graduate students with less preparation in the area, looking to become proficient in the quantitative analysis of biomedical phenomena would benefit most from this course. Pre requisites include multivariate calculus and differential equations.

Emphasis will be placed on enabling students to use currently available numerical methods (rather than developing anew) to solve engineering problems. Upon completing the course, the successful student will be able to use basic knowledge regarding computer architecture, data types, binary arithmetic, and programming, to solve sample quantitative problems in engineering. Topics will include: solving linear systems of equations, model fitting using least squares techniques (linear and nonlinear), data interpolation, numerical integration and differentiation, solving differential equations, and data visualization. Specific example computations in each topic above will be drawn from problems in physics, chemistry, as well as signal and image processing, and biomedical engineering. Students will work independently in groups for a final project. Matlab will be used as the programming language/environment for this class, although different languages such as C, Java, and Python will be briefly discussed (time permitting).
Objectives:

By the end of the course, the students should be able to describe the following:

1. be able to write Matlab scripts to load, manipulate, and save data
2. write Matlab programs to display and visualize data and results
3. write Matlab programs that are computationally efficient, through understanding basic concepts of computer architecture, arithmetic, data types, and programming
4. proficiently interpret and debug Matlab programs
5. simulate simple physical phenomena with Matlab
6. be able to find numerical solutions to sample problems in physics, chemistry, and engineering disciplines.
7. Work independently in groups to numerically solve a larger, nontrivial quantitative problem (through class project).

Required Textbook(s) or Other Materials:
- Michael R. King and Nipa A. Mody, Numerical and Statistical Methods for Bioengineering: applications in Matlab, Cambridge Texts in Biomedical Engineering (required)

Supplemental Textbook(s):

Instructor Contact Information:
- Email – gustavor@cmu.edu
- Telephone – 4122683684
- Office Location – HHC 120

Classroom Policy:
- Be courteous and aware of your surroundings
- Attendance of each class will not be recorded regularly
- Class participation, performance effort and improvement will be considered if a student’s grade is borderline between letter grade’ and the next higher letter grade (by example, D’, C’, and B’)

Reading and Homework Assignments:
- Readings will be assigned prior to covering a particular unit
- Homework assignments due on in class, on dates to be determined

Quizzes and Examinations:
- Quizzes every two weeks (approximately)
Grading:
- Homework assignments – 65%
- Quizzes – 10%
- Final project – 25%

Makeup Policy:
None, late assignments will be discounted 10% of that assignment’s grade per day late.

Grades:
- A=90-100%; B=80-90%; C=70-80%; D= 60-70%; R=<60%

Challenges to grades:
- The entire exam/assignment will be re-graded upon challenge, not just the challenged part

Schedule (tentative):
- Week 1: Introduction (Quantitative problems in BME, computer architecture)
- Week 2: Matlab overview (datatypes, vectors, basic calculations, loading & displaying data, basic programming, debugging).
- Week 3: Binary representation, arithmetic, error analysis.
- Week 4: Linear algebra
- Week 5: Numerical techniques for solving linear systems of equations
- Week 6: Linear regression, Applications
- Week 7: Root finding, nonlinear equations
- Week 8: Numerical integration
- Week 9 & 10: Ordinary differential equations I (IVPs, higher-order problems, stability, etc.)
- Week 11: Ordinary differential equations II (numerical solutions, stepsize control, etc.)
- Week 12 &13: Numerical Optimization
- Week 14: Numerical Optimization and Applications
- Week 15: Summary, & Project presentations
# Opportunities for Learning and Evaluation

Lectures
Homeworks
Quizzes
Projects
Final project presentations

<table>
<thead>
<tr>
<th>Program Outcome</th>
<th>Relation to Program Outcome</th>
<th>Mechanism</th>
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<tbody>
<tr>
<td>Ability to apply knowledge of mathematics, science, and engineering</td>
<td>Primary</td>
<td>Lectures, projects, homework, quizzes</td>
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<td>Ability to design and conduct experiments, as well as to analyze and interpret data</td>
<td>Primary</td>
<td>Project, homework</td>
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<td>Ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability</td>
<td>Primary</td>
<td>Project, homework</td>
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<td>Ability to function on multidisciplinary teams</td>
<td>Secondary</td>
<td>Project</td>
</tr>
<tr>
<td>Ability to identify, formulate, and solve engineering problems</td>
<td>Primary</td>
<td>Project, homework, quizzes</td>
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<td>Understanding of professional and ethical responsibility</td>
<td>Tertiary</td>
<td>Lectures, project</td>
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<td>Ability to communicate effectively</td>
<td>Secondary</td>
<td>Class project report &amp; presentation</td>
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<td>Broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context</td>
<td>Tertiary</td>
<td>Lectures</td>
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<td>Recognition of the need for, and an ability to engage in life-long learning</td>
<td>Primary</td>
<td>Lectures, project, homework</td>
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<td>Knowledge of contemporary issues</td>
<td>Tertiary</td>
<td>Lectures, project</td>
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<td>Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice</td>
<td>Primary</td>
<td>Project, homework</td>
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<td>Understanding of biology and physiology</td>
<td>Secondary</td>
<td>Lectures, homework, project</td>
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<tr>
<td>Capability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve the problems at the interface of engineering and biology</td>
<td>Primary</td>
<td>Lectures, project, homework, quizzes</td>
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<tr>
<td>Ability to make measurements on and interpret data from living systems</td>
<td>Secondary</td>
<td>Project, homework</td>
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<tr>
<td>Ability to address problems associated with the interaction between living and non-living materials and systems</td>
<td>Tertiary</td>
<td>Lectures, project, homework</td>
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