**Computer Science 400-Level**

**Numerical Methods for Scientific Computing and Machine Learning**

**Fall 2017**

**Dates / contact hours:** 300 minutes of contact time per week for 7 weeks; two sessions of 150 minutes each preferred by instructor

**Academic Credit:** 1 course

**Course format:** lecture + homework assignments + projects

**Instructor’s Information**

Xin Li  
Professor of Electrical and Computer Engineering, Duke and Duke Kunshan University

**Prerequisite(s), if applicable**

Undergraduate-level calculus, linear algebra, and probability

**Course Description**

Numerical methods is an important tool for scientific computing and machine learning problems such as image classification, thermal analysis, etc. The goal of this course is to teach a number of commonly-used algorithms, including linear solver, regression, classification, nonlinear optimization, etc., and, most importantly, how they can be used to solve practical engineering problems. This course will help to develop the mathematical skills to build customized algorithms, as well as the background required to use commercial tools.

**Course Goals / Objectives**

Students are expected to learn the basic algorithms and methodologies for scientific computing and machine learning, and implement prototype tools in MATLAB for these problems. Students should acquire the technical skills to: 1) apply knowledge of mathematics, science, and engineering, 2) design and conduct experiments, as well as analyze and interpret data, 3) identify, formulate, and solve engineering problems, and 4) use the techniques, skills, and modern engineering tools necessary for engineering practice.
Required Text(s)/Resources

Course slides will be provided at each lecture. No official textbook is required.

Recommended Text(s)/Resources


Additional Materials (optional)

None.

Course Requirements / Key Evidences

Students will learn the technical materials and acquire technical skills through lectures and homework assignments. They will learn to implement numerical algorithms via selected projects. One homework assignment will be given every week. It contains two or three questions and will be due in one week. Each homework assignment is expected to take 30-60 minutes to finish. In addition, three intensive course projects will be assigned, covering three different topics: 1) thermal analysis, 2) image processing, and 3) brain data classification. Students are required to write MATLAB code and a project report, and submit them at the end of each project. Each project is expected to take approximately 30 hours to finish.

There will not be official reading assignments associated with this course. When students work on homework and project assignments, they are expected to read the recommended books or other online resources, develop problem-solving skills, and formulate their solutions, instead of following a step-by-step recipe provided by the instructor. The majority of the material will be presented during classroom lectures and the majority of student effort will be in problem-solving and code-writing. Students are expected to spend 15-30 minutes to read reference books and online resources every week. The estimated time previously mentioned for homework assignments and projects indicates the overall workload for these assignments (i.e., reading reference books and online resources, solving homework problems, programming MATLAB, writing project reports, etc.).

Technology Considerations, if applicable

Students need to use their laptop computers installed with MATLAB

Assessment Information / Grading Procedures

The course grade will be calculated based on the following:
30%: Homework assignments
20%: Project 1
Diversity and Intercultural Learning (see Principles of DKU Liberal Arts Education)

This course covers a variety of applications related to scientific computing and machine learning in diverse communities. Given its broad coverage, students with diverse background are expected to take the course. The interactions of these students through learning, discussion, and collaboration will form an intercultural educational environment.

Course Policies and Guidelines

Academic Integrity:
Each student is bound by the academic honesty standard of the Duke Kunshan University. Its Community Standard states: “Duke Kunshan University is a community composed of individuals of diverse cultures and backgrounds. We are dedicated to scholarship, leadership, and service and to the principles of honesty, fairness, respect, and accountability. Members of this community commit to reflect upon and uphold these principles in all academic and non-academic endeavors, and to protect and promote a culture of integrity.”

Class Attendance:
Class attendance is mandatory. All students are expected to participate during class time.

Make-up Work:
Students are allowed to make up work only for medical reasons, consistent with DKU policy. You must notify the instructor in advance if you will miss a deadline for homework or project. Documentation from a health care provider is required upon your return to class.

Digital Device:
Using laptop, cell phone or other digital devices in classroom is prohibited.

Tentative Course Outline or Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture topics</th>
<th>Project schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction, MATLAB tutorial, ordinary differential equation, numerical integration, stability, partial differential equation, thermal analysis, finite difference</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Gaussian elimination, condition number, LU factorization, Cholesky decomposition, linear regression, design of experiments</td>
<td>Project 1</td>
</tr>
<tr>
<td>3</td>
<td>Convex function, convex set, convex optimization, Pseudo-inverse, QR decomposition, over-fitting, regularization, compressed sensing, orthogonal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>matching pursuit</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>
| 4 | Newton-Raphson method, binary search, gradient method, Newton method, linear equality constraint, Lagrange multiplier | Project 2  
| 5 | Inequality constraint, interior point method, Lagrange dual, KKT condition, classification, support vector machine, regularization |  
| 6 | Conjugate gradient method                                                        | Project 3  
| 7 | Monte Carlo analysis, principal component analysis, dimension reduction, random walk, stochastic optimization |  

Revised version based on comments from Reisinger committee (29 October 2016)