Course Description: Scientific computing is a broad and constantly evolving area that involves theories, algorithms and tools to solve scientific and engineering problems. Starting with the classical background on numerical errors and their propagation, we will continue with basic matrix computations such as solving linear systems, eigenvalue problems and least squares problems on computers. Then, we will study algorithms for large scale matrix operations, including randomized methods. Followed by compressive sensing and matrix completion. Towards the end of the course, we will study numerical optimization, leading us to gradient descent type of algorithms and if time permits we will go over automatic differentiation. This is not a machine learning or data analytics course, but we will cover most algorithms that play a central role in not only in these areas but also in other scientific and engineering computations.

Instructor:
Murat Manguoglu
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Email: manguoglu@ceng.metu.edu.tr
Office hours: Thursday 14:00-15:00

Teaching assistant: TBD

Schedule:
Wednesday 15:40-17:20 BMB5
Thursday 11:40-12:20 BMB5
(Based on the covid regulations, each hour is 40 minutes long with a 20 minutes long break in between, we will meet in class only and there will be no live or recorded lecture videos)

Textbook: Linear Algebra and Learning from Data by Gilbert Strang

Supplementary Textbooks:
Introduction to Scientific Computing by Charles Van Loan
Numerical Analysis: Mathematics of Scientific Computing by Kincaid and Cheney
Scientific Computing: An Introductory Survey by Micheal T. Heath

Grading: The grading policy is listed below. Exam dates will be announced later.

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Midterm</td>
<td>25%</td>
</tr>
<tr>
<td>Homeworks (×4)</td>
<td>40%</td>
</tr>
<tr>
<td>Final</td>
<td>35%</td>
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Homeworks: There will be 4 programming homework assignments. Delayed submissions are accepted with a penalty of $-5 \times d^2$ where $d$ is the number of days in which the solution is submitted late.
• **Examinations** Midterm and final are closed book and notes. Only one page (no larger than A4) and **hand written** cheat sheet is allowed. Time and location will be announced later.

• **Attendance and Participation**
  Attendance and participation in the class and office hours are encouraged. I will randomly check attendance and I may use it in your favor when assigning letter grades.

• **Communication:**
  Announcements about the course will be made in class and on odtuclass. Please attend the class and follow odtuclass announcements.

• **Academic Integrity:**
  All homeworks, midterm and final are expected to be individual work. Discussion of ideas or concepts are allowed and encouraged for the homeworks. However, when writing your code or solution you should not look at other people’s work. If you use a source (online or offline) you are expected to cite it. Violation of these general principles will be handled based on the university regulations and may result in disciplinary action.

• **Outline:** (tentative)
  - Errors and error propagation: source of errors, error propagation and estimation, condition numbers and numerical stability of algorithms
  - Direct solution of linear systems: Gaussian elimination and LU factorization, LU factorization with pivoting and error analysis, Householders reflection, QR factorization and error analysis
  - Solution of eigenvalue problems: Introduction to symmetric eigenvalue problems, power iteration, inverse iteration and Rayleigh quotient iteration
  - Least squares approximations: overdetermined linear least squares, curve fitting, normal equations, solution of underdetermined linear least squares, singular value decompositions.
  - Large matrix computations and randomized linear algebra: iterative methods for solving linear systems, randomized matrix multiplication, factorization and approximations.
  - Compressed sensing and matrix completion
  - Optimization: convexity and Newton’s methods, linear programming, gradient descent and stochastic gradient descent.
  - Automatic differentiation (backpropagation)