CENG 371 - Scientific Computing

Middle East Technical University
Department of Computer Engineering

Syllabus
Fall 2025 v1.0

- **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 not only in these areas but also in other scientific and engineering computations.

- **Instructor:**

  Murat Manguoğlu
  Office: A407, Phone: 210 5551
  Email:*manguoglu[at]ceng.metu.edu.tr*
  Office hours: Tuesday 9:30-10:30

- **Teaching assistant:**

  TBD

- **Schedule:**

  Monday 15:40-17:30 BMB4
  Tuesday 10:40-11:30 BMB4

- **Prerequisites:** Calculus and linear algebra are required.

- **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
  Numerical Methods in Scientific Computing, Volume I by Germund Dahlquist, Ake Bjorck
  Scientific Computing: An Introductory Survey by Micheal T. Heath

- **Grading:** (tentative) The grading policy is listed below. Exam dates will be announced later.

Midterm	35%
Final	45%
Homeworks (×4)	20%

- **Homework:** 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** The midterm and final are closed book and notes. Only one page (no larger than A4) and **hand-written** cheat sheet is allowed. The time and location will be announced later.
- **Makeup policy:** In case of an official medical or family emergency that prevented you from attending the final or submitting any of the homeworks on time, you should contact the instructor as soon as possible and provide documentation.
- **Attendance and Participation** Attendance and participation in 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 homework, midterm, and final are expected to be individual work. Discussion of ideas or concepts are allowed and encouraged for the homeworks. However, your code and report should be your own work, without any outside assistance (which obviously includes generative AI tools). If you use a source (online or offline) you are expected to cite it. Violation of these general principles will be handled according to 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[**if time permits**].