

CMPE 482 - Numerical Linear Algebra and Its Applications (online)

Spring 2021

Instructor: Ali Taylan Cemgil
TA (Voluntary): Melih Barsbey, Burak Kurutmaz

Bogazici University,
Department of Computer Engineering, Istanbul, Turkey
Th 9:00-12:00 (Istanbul Time)



Important announcement for taking CMPE482 in Spring 2021 for credit

Prerequisite: Ability (or willingness to learn) programming in Python (numpy, scipy, jax) and preparing reports on a jupyter/colab notebooks using latex. We won't teach programming but yet programming projects will be an important part for understanding the material.

CmpE students: Consent is required.

non CMPE majors: this course requires basic programming skills and computational thinking. We will consider each consent request separately and we will approve your request with some delay (possibly by the last day of registration) and only if there are enough empty spots.

Description

Numerical linear algebra (NLA) provides a set of basic methods that are useful for developing algorithms for a diverse spectrum of applications in data processing.

You would need little bit of calculus, but that is about it as a prerequisite to follow this material.

If you are interested in machine learning (ML) or deep learning, this course will be useful, but this is not a ML course. Our goal in this course is to provide an overview of numerical linear algebra, along with applications chosen particularly related to machine learning.

Main Textbooks

[Introduction to Applied Linear Algebra – Vectors, Matrices, and Least Squares](#), Cambridge University Press, Stephen Boyd and Lieven Vandenberghe

[\(Slides\)](#)

[\(Python Language Companion\)](#)

This is a fairly introductory text. We plan to cover most of this material until the spring break. The Python companion is useful for implementing the ideas in a colab/jupyter notebook.

[Mathematics for Machine Learning](#), (2020) Marc Peter Deisenroth, A. Aldo Faisal, and Cheng Soon Ong. Cambridge University Press

After the spring break, we will provide further references to delve deeper into selected topics here.

Further References

Trefethen, Lloyd N. and Bau III, David; (1997). Numerical linear algebra. Philadelphia: Society for Industrial and Applied Mathematics. ISBN 978-0-89871-361-9

This is the de-facto text for fundamentals. It used to be our main text book. It is recommended that you read the first part of this book. We will still use some material from this book related to SVD, QR and orthogonal projections.

Golub, Gene H.; van Loan, Charles F. (2013), Matrix Computations, 4th edition, Johns Hopkins University Press, ISBN 978-0-8018-5414-9

The classic. For the true connoisseur.

Computer Usage

We will use numpy and jax on top of python on jupyter/colab notebooks.

See: [JAX](#)

Plan

IALA: *Introduction to Applied Linear Algebra*, Boyd et al. 2018

IALA-Vid: Stephen Boyd's videos

IALA-Py: Python Companion

MML: *Mathematics for Machine Learning*, Deisenroth et al. 2020

Both books are freely available online.

	Date	Topics	Material	Additional tasks
1	18.03.2021	Linear algebra basics recap: Vectors, linear functions, norm and distance, (Taylor approximation, Regression model, Cauchy–Schwarz inequality, Chebyshev inequality, Gradient vector)	IALA Ch. 1, 2, 3 IALA-Vid 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16	
2	25.03.2021	Basis, linear independence, orthonormal vectors Matrices, linear and affine functions (Gram-Schmidt algorithm, Jacobian matrix)	IALA Ch. 5, 6, 7, IALA-Vid 15, 16	
3	01.04.2021	System of linear equations, Linear Dynamical Systems, Matrix multiplication and power, QR factorization, matrix inverses, pseudo-inverse	IALA Ch. 8, 9, 10, 11	
4	08.04.2021	Least squares, model selection	IALA Ch. 12, 13, 14	Assignment #1 due
5	15.04.2021	Multi-objective least squares, constrained least squares	IALA Ch. 15, 16, 17	
6	22.04.2021	Nonlinear least squares, constrained nonlinear least squares	IALA Ch. 18, 19	Assignment #2 due
7	29.04.2021	Linear algebra review, determinant, trace, eigendecomposition, Cholesky decomposition	MML Ch. 4	
8	06.05.2021	Singular value decomposition, matrix factorization	MML Ch. 4	Assignment #3 due
9	13.05.2021	SPRING BREAK		
10	20.05.2021	Vector calculus, partial differentiation, gradient, Jacobian	MML Ch. 5	Assignment #4 due
11	27.05.2021	Vector calculus recap, backpropagation, automatic differentiation	MML Ch. 5	
12	03.06.2021	Continuous optimization, stochastic gradient descent, constrained optimization,	MML Ch. 7	Assignment #5 due

13	10.06.2021	Convex optimization, automatic differentiation applications	MML Ch. 7	
----	------------	---	-----------	--

JAX tutorials

- [Jax Quickstart](#)
- [Jax Demonstration](#)
- [JAX, aka NumPy on steroids](#)
- [Tutorial about internal workings of JAX](#)

These JAX tutorials assume familiarity with Python scientific computation stack (numpy, scipy, Pandas etc.). There are many helpful tutorials on the web for introduction or review of this material. An introductory level familiarity should get you most of the way.

Administrative

- Assignments and Projects %60 (5-6)
- Written Exam %40 (Final)
- Total Credits: 3

Dedication

This course is dedicated to the memory of our colleague and friend Ismail Ari (1983-2013).