Intro and First Day Stuff

Lecture 1 - CMSE 382

Prof. Elizabeth Munch

Michigan State University
::
Dept of Computational Mathematics, Science & Engineering

Mon, Jan 12, 2026

Groups - Round 1

Group 1
Jonid M.
Sanskaar M.
Andrew B.
Zheng Y.

Group 2
Abigail P.
Braedon P.
Vinod R.
Aidan S.

Group 3
Luis C.
Tianjian X.
Lowell M.
Arjun R.

Group 4
Jay B.
Maye B.
Jamie L.
Kyle S.

Group 5
Aaron N.
Purvi G.
Morgan F.
Breena K.

Group 6
Brandon G.
Dominic V.
K M Tausif S.
Anthony K.

Group 7
Monirul Amin M.
Daniel E.
Quang Minh D.
Ha N.

Group 8
Lora S.
Jack C.
Noah M.
Michal T.

Group 9
Atticus B.
Shanze O.
Joseph M.
Arya S.

Group 10
Scott W.
Karen S.
Dev Jyoti Ghosh A.
Dori C.

Group 11
Saitej B.
Jake R.
Alice S.
Long N.

Group 12
Lauryn C.
Sai P.
Yousif E.

People in this lecture

Dr. Munch (she/her)
Depts of CMSE and Math

Omeiza Olumoye
Graduate Student, CMSE, MSU

What is this course about?

Machine Learning Pipeline

Finding the Optimum

There will be calculus! And matrices!

Course Outline

Nonlinear Optimization

Mathematical Preliminaries
Chapter 1

Course Topics Include:
- Linear Programming
- Nonlinear Programming
  - Convex Problems
  - Non-convex Problems
- Applications

Unconstrained Optimization

Optimality Conditions For Unconstrained Optimization
Chapter 2

Applications of Unconstrained Optimization
Chapter 3

Numerical Methods For Unconstrained Optimization
Chapter 4
Chapter 5

Applications Include:
- Least Squares
- Data Fitting
- Denoising

Constrained Optimization

Convexity Concepts
Chapter 6
Chapter 7

Convex Optimization
Chapter 8
Chapter 9

Linearly Constrained Problems
Chapter 10

Inequality and Equality Constrained Problems
Chapter 11

Duality
Chapter 12

Applications Include:
- Linear Programming
- Linear Separator
- Chebyshev Center
- Orthogonal Projections

Course Website and where to find slides and jupyter notebooks

https://elizabethmunch.com/CMSE382

–or–

https://msu-cmse-courses.github.io/cmse382-spring2026/

Note the syllabus link above!

D2L and where to find grades

https://d2l.msu.edu/d2l/home/2387926

Crowdmark and where to submit assignments

No URL: You should already have an automated email from the system. If not, talk to me once we're doing group work.

Office hours

Zoom link and schedule:

https://msu-cmse-courses.github.io/cmse382-spring2026/help/#office-hours

Dr. Munch

Time TBD (Starting next week)

Zoom & EGR 1511

Omeiza Olumoye

Time TBD

Zoom & EGR (Room TBD)

Textbook

Introduction to Nonlinear Optimization by Amir Beck.

Free download from MSU Library Website. More info:

https://msu-cmse-courses.github.io/cmse382-spring2026/textbook/

Class Structure

- Most classes have videos to watch before class. These will be posted on the course website and D2L.
- Class is a brief review of the video content, and group work/coding time. In-class worksheets will be graded on completion.
  - Bring computer every day
  - Jupyter notebooks
  - Python
  - In-class worksheets graded on completion. No credit unless present in class. 5 drops.
- Approximately every two weeks there is a 15 minute quiz at the end of class.
  - Drop one lowest grade
  - Can bring a cheat sheet

Class Structure Pt 2

- Homeworks due approximately every 2 weeks.
  - Drop two lowest grades
  - Sliding scale:
    - 24 hours late: 5% penalty.
    - 48 hours late: 10% penalty.
    - $>$48 hours: No late work accepted.
- Three Midterms
  - See schedule for dates
  - Not cumulative
- One Project
  - Analyze dataset using tools in class, submit written report
  - 100 points
  - Due at the end of the semester

Collaboration and Generative AI Policy

- You may use generative AI tools (e.g., ChatGPT, Bard, DALL-E) for brainstorming, drafting, and coding assistance on homework assignments.
- You must clearly indicate any use of generative AI tools in your submissions, specifying the tool used and the nature of its contribution.
- You may discuss homework problems with classmates, but all submitted work must be your own.
- No collaboration or use of generative AI tools is allowed on quizzes and exams.

Approximate schedule

msu-cmse-courses.github.io/cmse382-spring2026/schedule/

Grade distribution

	Number	*Number drops*	*Percentages*
Homeworks	6	2	40%
In-class worksheets	~ 30	5	10%
Quizzes	6	1	10%
Midterm	3	0	40%

Section 1

Math Preliminaries - Part 1

Today's content

- The space $\mathbb{R}^n$
- Inner products
- Vector norms
- Cauchy Schwarz inequality

The space $\mathbb{R}^n$

Definition

The space $\mathbb{R}^n$ is the set of n-dimensional column vectors with real components.

- Addition:

$$\begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{pmatrix} + \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix} = \begin{pmatrix} x_1 + y_1 \\ x_2 + y_2 \\ \vdots \\ x_n + y_n \end{pmatrix}$$

- Scalar multiplication:

$$\lambda \cdot \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{pmatrix} = \begin{pmatrix} \lambda x_1 \\ \lambda x_2 \\ \vdots \\ \lambda x_n \end{pmatrix}$$

Standard basis

Definition

The standard basis vectors in $\mathbb{R}^n$ are the vectors

$$e_1 = \begin{pmatrix} 1 \\ 0 \\ \vdots \\ 0 \end{pmatrix}, \quad e_2 = \begin{pmatrix} 0 \\ 1 \\ \vdots \\ 0 \end{pmatrix}, \quad \ldots, \quad e_n = \begin{pmatrix} 0 \\ 0 \\ \vdots \\ 1 \end{pmatrix}.$$

The space $\mathbb{R}^{m\times n}$

Definition

The space $\mathbb{R}^{m\times n}$ is the set of m by n matrices with real components.

Special matrices:

- Identity matrix: I_n
- Zeros matrix: $0_{m\times n}$

Inner Product

Definition

An inner product on $\mathbb{R}^n$ is a function $\langle \cdot, \cdot \rangle : \mathbb{R}^n \times \mathbb{R}^n \to \mathbb{R}$ that satisfies the following properties for all $x, y, z \in \mathbb{R}^n$ and $\alpha \in \mathbb{R}$:

- **Symmetry:** $\langle x, y \rangle = \langle y, x \rangle$
- **Additivity:** $\langle x, y + z \rangle = \langle x, y \rangle + \langle x, z \rangle$
- **Homogeneity:** $\langle x, \lambda y \rangle = \lambda \langle x, y \rangle$
- **Positive-definiteness:** $\langle x, x \rangle \geq 0$ with equality if and only if $x = 0$.

Example: dot product

$$\langle x, y \rangle = x^\top y = \sum_{i=1}^{n} x_i y_i.$$

Vector Norms

Definition

A norm on $\mathbb{R}^n$ is a function $\|\cdot\| : \mathbb{R}^n \to \mathbb{R}$ that satisfies the following properties for all $x, y \in \mathbb{R}^n$ and $\lambda \in \mathbb{R}$:

- **Nonnegativity:** $\|x\| \geq 0$ with equality if and only if $x = 0$
- **Positive homogeneity:** $\|\lambda x\| = |\lambda|\|x\|$
- **Triangle inequality:** $\|x + y\| \leq \|x\| + \|y\|$

Example: ℓ_p norm for $p \geq 1$:

$$\|x\|_p = \left(\sum_{i=1}^{n} |x_i|^p \right)^{1/p}.$$

Norms from inner products

Given an inner product $\langle \cdot, \cdot \rangle$ on $\mathbb{R}^n$, we can define a norm by

$$\|x\| = \sqrt{\langle x, x \rangle}.$$

Example:

Given the dot product, we have the Euclidean norm, also called the ℓ_2 norm:

$$\|x\|_2 = \sqrt{x^\top x} = \sqrt{\sum_{i=1}^{n} x_i^2}.$$

Caucy-Schwarz Inequality

Lemma (Cauchy-Schwarz Inequality)

For any $x, y \in \mathbb{R}^n$,

$$|x^T \cdot y| \leq \|x\|_2 \cdot \|y\|_2.$$

Written another way and for more general inner products,

$$|\langle x, y\rangle| \leq \|x\| \cdot \|y\|.$$

Example:

$$x = \begin{pmatrix} -3 \\ 4 \\ 0 \end{pmatrix}, \qquad y = \begin{pmatrix} 0 \\ -5 \\ 12 \end{pmatrix}$$

Group Work Time

- Introduce yourself to your group members
- Find and download the worksheet from the course website.
- In the last 10 minutes of class, you will upload your completed worksheet to D2L. Note: graded on completion only.

Next time

- Watch videos posted on the course webpage
- Check syllabus dates - Especially exam, homework, and quiz dates
- Office hours