CMSC 838B & 498Z: Differentiable Programming

Tues/Thur 2:00pm – 3:15pm

http://www.cs.umd.edu/class/fall2026/cmsc838b

Ming C. Lin

IRB 5162

lin@cs.umd.edu

http://www.cs.umd.edu/~lin

Office Hours: After Class or By Appointment

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Prerequisities

- **CMSC 330**
- **CMSC 351**
- **CMSC 422 (or CMSC 421)**

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What you should know?

- **Fundamentals of statistical learning, MLPs, gradient descent, how to train and evaluate learning machines, supervised-vs-unsupervised, reinforcement learning, etc.)**
- **Fundamentals of:**

Matrix Algebra (matrix-matrix, matrix-vector and matrix-scalar operations, inverse, determinant, rank, Eigendecomposition, SVD); Probability & Statistics (1st-order summary statistics, simple continous and discrete probability distributions, expected values, etc); and, Multivariable Calculus (partial differentiation, chain-rule).

- **Programming in Python (not required)**

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What you might already know?

- **How to use a deep learning framework (Keras, Tensorflow, PyTorch)?**
- **How to train an existing model architecture using a GPU?**
- **How to perform transfer learning?**
- **How to perform differentiable sampling of a Multivariate Normal Distribution?**

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Textbook & References

- In-class handouts
- Other research papers
- More references (books, papers, pointers to other interesting resources) available at the course website

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Differentiable Programming

- a novel programming paradigm, where programs are treated as compositions of differentiable operations that can then be optimized to fit data with tremendous possibility to transform how we can utilize computers to perform calculations on “big data”
- application to significantly accelerate performance for Agentic AI and Physical Intelligence systems

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Differentiable Programming

- Coined by Yann Lecun[1] to describe a *superset of Deep Learning*
- Captures the idea that computer programs can be constructed of *parameterized functional blocks* in which the parameters are learned using some form of *gradient-based optimization*
- The implication is that we need to be able to compute gradients with respect to the parameters of these functional blocks. We'll start explore this in detail next week...
- The idea of Differentiable Programming also opens up interesting possibilities:

1) The functional blocks don't need to be direct functions in a mathematical sense; more generally they can be *algorithms*.
2) What if the functional block we're learning parameters for is itself an algorithm that optimizes the parameters of an internal algorithm using a gradient based optimizer?!

- [1] https://www.facebhttps://www.facebook.com/yann.lecun/posts/10155003011462143

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Course Objectives

- Have an overview of the underlying mathematical and algorithmic principles of differentiation
- Understand the key factors that make differentiable programming successful for various applications

- Be able to read papers on differentiable programming
- Gain facility in working with differentiable programming
- Critically appraise the merits and shortcomings of different methods on specific problems

- Apply differentiable programming to real applications

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Possible Applications

- Bioinformatics
- Computer Architecture
- Computer Graphics
- Computer Vision
- Programming Languages
- Natural Language Processing
- Quantum Computing
- Robotics and Automation

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Topics Covered (Tentative)

- Overview & Introduction (Tues, Sept 1, 2026)
- Background and Reviews (Thur, Sept 3, 2026)
- Differentiation (Tues, Sept 8, 2026)
- Differentiable Programming (Thur, Sept 10, 2026)
- Automatic Differentiation (Tues, Sept 15, 2026)
- MLP & Backpropagation (Thur, Sept 17, 2026)
- Optimization (Tues, Sept 22, 2026)
- Differentiable Meshes (Thur, Sept. 24, 2026)
- Differentiable Physics (Sept/Oct 2026)
- Differentiable Rendering (Oct, 2026)
- Differentiable Geometry Processing (Oct, 2026)
- Differentiable Image Processing (Oct, 2026)
- Differentiable Vision (Oct, 2026)

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Topics Covered

- Project Proposal (Oct. 2026)
- Special Topics (October-December 2026)
- Course Project Progress Report (Nov. 2026)
- NO CLASS: THANKSGIVING BREAK
- Final Course Project Presentation (Dec. 2026)

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Grading

- 1-Credit Option
  - Participation (100%)
- 3-Credit Option
  - In-Class Exams (30%)
  - Class Presentation & Participation (20%)
  - Final Course Project (50%)
    - In-Class Presentations: Proposal/Progress/Final
    - Large-scale Programming & Software Engineering

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In-Class Exams (30%)

- Midterm Examination (15% of class grade)
  Thursday, Oct 1, 2026
- Final Oral Exam (5% of class grade)
  December 17, 2026
- Final Written Exam (10% of class grade)
  December 18, 2026

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Student Class Presentations (20%)

- By Oct 6, 2026 - Choose a presentation topic and inform the instructor
- One week before the presentation - Submit a draft of presentation materials and select a 'discussant' to lead Q&A
- One lecture before the presentation - Hand out copies of reading materials, if not avail online
- One day before the presentation - Post the presentation materials on the web

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Student Class Presentations (20%)

- Advanced Preparation according to the Specification (40%)
- Analysis and Discussion of the Materials (40%)
- Style and Clarity of the Actual Presentation (20%)

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Final Course Project (50%)

Project Proposal Presentation (5%)
Project Progress Presentation (5%)
Concept Integration from Course (10%)
Originality and Creativity (10%)
System Implementation & Demos (20%)

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Final Course Project

Oct 6, 2026 - Meet with Instructor to discuss project ideas
Oct 20-22, 2026 - Project Proposal Presentations
Nov 17-19, 2026 - Proress Report
Dec 17, 2026 - Final Project Presentation & Demo

- **Final Oral Exam (5% of class grade)**
  December 17, 2026
- **Final Written Exam (10% of class grade)**
  December 18, 2026

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Possible Project Ideas

- **Parameter Estimation of Dynamical Systems**
- **Parameter Optimization for Quantum Computers**
- **System Identification for Complex Structures**
- **Motion Control of Traffic Flows**
- **Motion Control of Multi-Agent Systems**
- **Agentic AI Systems**
- **Physical Intelligence**
- **Foundation Models Using Diff Programming**

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See Course Website

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for more details……

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