Name:

CMSC 838B & 498Z: Differentiable Programming

Tues/Thur 12:30pm – 1:45pm

http://www.cs.umd.edu/class/fall2021/cmsc838b

Ming C. Lin

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Office Hours: After Class or By Appointment

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Prerequisities

- **CMSC 330**
- **CMSC 351**
- **CMSC 422**

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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)**
- **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”

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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.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

- Overview & Introduction (Tues, Aug 31, 2021)
- Background and Reviews (Thur, Sept 2, 2021)
- Differentiation (Tues, Sept 7, 2021)
- MLP & Backpropagation (Thur, Sept 9, 2021)
- Differentiable Programming (Tues, Sept 14, 2021)
- Automatic Differentiation (Thur, Sept 16, 2021)
- Optimization (Tues, Sept 21, 2021)
- Differentiable Physics (Thur, Sept. 23, 2021)
- Differentiable Rendering (Tues, Sept 28, 2021)
- Differentiable Rendering (Thur, Sept 30, 2021)
- Differentiable Geometry Processing (Tues, Oct 5, 2021)
- Differentiable Image Processing (Thur, Oct 7, 2021)
- Differentiable Vision (Tues, Oct 12, 2021)

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Topics Covered

- **Project Proposal (Thur, Oct 14, 2021)**
- Special Topics (Tues, Oct 19, 2021)
- Project Meeting (Thur, Oct 21, 2021)
- Special Topics (Tues, Oct 26, 2021)
- Project Meeting (Thurs, Oct 28, 2021)
- Special Topics (Tues, Nov 2, 2021)
- Project Meeting (Thurs, Nov 4, 2021)
- Special Topics (Tues, Nov 9, 2021)
- Project Meeting (Thur, Nov 11, 2021)
- Special Topics (Tues, Nov 16, 2021)
- **Course Project Progress Report (Thur, Nov 18, 2021)**
- Special Topics (Tues, Nov 23, 2021)
- NO CLASS: THANKSGIVING BREAK (Thur, Nov 25, 2021)
- Special Topics (Tues, Nov 30, 2021)
- Project Meeting (Thurs, Dec 2, 2021)
- Special Topics (Tues, Dec 7, 2021)
- Project Meeting (Thurs, Dec 9, 2021)

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Grading

- **1-Credit Option**
  - **Participation (100%)**
- **3-Credit Option**
  - **Participation (35%)**
  - **Final Course Project (65%)**
    - **In-Class Lecture**
    - **Large-scale Programming & Software Engineering**

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See Course Website

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for more details……

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