DS 6050: Deep Learning (Spring 2023)

(Last Modified: 01/23/2023)

Course Overview

This is a graduate-level course on deep learning, aiming to cover fundamental concepts for deep neural networks and their applications. Topics include multi-layer perceptron, backpropagation, convolutional neural networks, recurrent neural networks, generative networks, deep reinforcement learning, interpretable deep learning, etc. The course will focus on hands-on learning activities using open-source Python libraries such as NumPy, scikit-learn, and PyTorch. Students are required to have sufficient computational background to complete several substantive programming assignments.

- **Class Level and Credit Type**: Graduate; Graded
- **Lecture Time**: 2PM – 3:15PM, Mondays & Wednesdays
- **Location**: Ridley Hall G004

Instructor Information

Dr. Sheng Li
Assistant Professor, School of Data Science
Email: shengli@virginia.edu
Website: http://sheng-li.org/
Instructor Office Hour & Location: 11AM – 12PM (Mondays), 178 Elson

TA Information

- **Zhanwen Chen** (PhD Student, School of Data Science)
  Email: pct4et@virginia.edu
  TA Office Hour and Location: 1:00PM - 2:00PM (Wednesdays) at Dell 1 (round table in public space) or by appointment on Zoom (https://virginia.zoom.us/my/zhanwenchen).
- **Jiahao Tian** (PhD Student, School of Data Science)
  Email: jt5uc@virginia.edu
  TA Office Hour and Location: 10:00AM - 10:30AM (Thursdays) at Dell 1 (public space)

Textbook/Readings

- Goodfellow, Bengio, and Courville, ***Deep Learning*** (Cambridge, MA: MIT Press, 2016).
  Free online copy of this book is also available at: http://www.deeplearningbook.org/
- Antiga, Stevens, Viehmann, ***Deep Learning with PyTorch*** (Manning Publications, 2020).
  Online available at: https://www.oreilly.com/library/view/deep-learning-with/9781617295263/

* The field of deep learning is rapidly evolving. To keep up with the newest trends, the course will also be based largely on conference publications and online materials.

Delivery Mode

In-person lecture & Online discussions

Required Technical Resources

- Google Colaboratory (https://colab.research.google.com)

Communication

A discussion board is set up for each module, which is designed to be the place where students can reach out to peers and instructors and ask questions related to the course content and technology. Students are encouraged to check the discussion boards daily for updates or other correspondences. Emails are less preferred but can certainly be a medium for communication, especially when privacy is needed. In any case, throughout our time together, the sooner you inform me of any problem (personal or academic) that may affect your attendance or performance, the better the chance we have of solving it together.

Learning Outcomes

Upon successful completion of this course, you will be able to:

1. Create an end-to-end machine learning project at scale using open-source libraries such as NumPy, scikit-learn, and PyTorch.
2. Formulate various supervised, unsupervised, and reinforcement learning models.
3. Apply practical skill sets on designing, deploying, and analyzing deep network architectures on complex real-world problems.
4. Articulate concepts, algorithms, and tools to build intelligent systems.
5. Analyze advanced approaches currently pursued by the machine learning community

Prerequisites

Prior to taking this course, you should meet the following prerequisites:

- At least one programming course
- Regression analysis
- Machine learning/data mining

The following are strongly recommended:

- Programming in Python (since Python will be used in this course)
- At least one course in linear algebra, statistics, and multivariate calculus

Class Schedule

Classes will be held on Mondays and Wednesdays from 2:00 PM – 3:15 PM Eastern Time. Below is a list of specific dates and the topics to be covered (subject to change).

Module	Date	Topic	Note
0. Introduction	01/18	Welcome & Course Overview	
1. Machine Learning Recap	01/23	Mathematical Foundations of Deep Learning	
	01/25	Introduction to Machine Cognition	
2. (Shallow) Artificial Neural Networks	01/30	Multi-Layer Perceptron	
	02/01	Backpropagation	A1 Assigned
3. Convolutional Neural Networks	02/06	Convolutional Neural Networks (CNN)	
	02/08	Basic Building Blocks of CNN	
4. How to Train Your CNN – Part I	02/13	Data Distribution, Regularization	A1 Due
	02/15	Data Processing, Augmentation	A2 Assigned
5. How to Train Your CNN – Part II	02/20	Optimization Methods	
	02/22	Loss Functions & Other Tips	
6. CNN Architectures	02/27	Early CNN Architectures	
	03/01	Modern CNN Architectures	A2 Due
Spring Break	03/06	No Class	
	03/08	No Class	
Project Planning Week	03/13	Project Overview + Q&A	
	03/15	Proposal Workday	
7. Visualization of CNNs	03/20	Learned Features/Concepts, Saliency Maps	
	03/22	Adversarial Examples, Other XAI Methods	
8. Object Detection	03/27	Region-based CNN (R-CNN Family)	
	03/29	Single-shot Detectors	
9. Recurrent Neural Networks	04/03	RNN Basics	A3 Assigned
	04/05	Transformer Networks	Checkpoint
10. Generative Networks	04/10	Encoder-Decoder Architecture	
	04/12	Generative Adversarial Networks (GAN)	
11. Overview of Advanced Topics	04/17	Deep Reinforcement Learning	A3 Due
	04/19	Graph Neural Networks, Diffusion Models, Vision Transformers, etc.	
Final Project Week	04/24	Final Presentation	
	04/26	Final Presentation	
Course Review	05/01	Course Review & Summary	Project Due

Evaluation Standards and Assessment

Programming Assignments	Programming assignments will be implemented in Jupyter Notebooks and provide hands-on experience writing/modifying Python/PyTorch code while working with various datasets.
Module Quizzes	At the end of each module, a module quiz will assess student knowledge and application of topics covered in reading assignments and modules.
Discussions	For each module, students are encouraged to actively participate in a discussion on relevant topics, questions, etc.
Group Project	The group project is a large component of the course; it includes students working in groups of three to work on a real-world deep learning challenge. Groups are free to choose their own topic of interest from sponsored projects (TBA), public data science competitions (e.g., Kaggle), or other areas of deep learning research and/or applications. The project consists of four major milestones: topic selection/proposal, progress checkpoint, presentation, and final report.

Assignments will be graded according to the following breakdown:

Assignment	Total Points	Percentage	Modules
3 Programming Assignments	300 (3 x 100) pts	30%	M2, 3-6, 9
10 Quizzes	200 (10 x 20) pts	20%	Pick 10 from M1-11
10 Discussions	100 (10 x 10) pts	10%	Pick 10 from M1-11
1 Group Project	400 (1 x 400) pts	40%	M1-11

The final letter grade will be determined by the following scale:

Grade	From	To
A+	980	1,000
A	930	979
A-	900	929
B+	870	899
B	830	869
B-	800	829
C+	770	799
C	730	769
C-	700	729
D+	670	699
D	630	669
D-	600	629
F	0	599

Programming Assignments

There will be three programming assignments. Each assignment will be graded for correct implementation, results, a thorough discussion of the results, and good organization, grammar, and spelling. This is a programming course and doing the programming assignments is absolutely critical (and accounts for 30% of your grade). If the results you see when running your program do not match the results that the TA reports for your program, you should talk to the TA promptly. However, in all but the rarest of cases, you should be prepared to understand that the definitive test of your code is that made by the TA, and what you are seeking in talking to the TA is an understanding of how to avoid losing points over similar discrepancies in the future. To put this another way, you should contact the TA, but if you understand why there is a difference, you should not assume that your assignment will be re-graded.

Module Quizzes

There will be a total of 11 quizzes. Each quiz will assess student knowledge and application of topics covered in reading assignments and modules. Any quiz that is missed due to an absence that is not a university-excused absence will result in a zero (0) for that grade. Any quiz that is missed due to a university-excused absence or due to circumstances that are approved by me beforehand must be made up within a week of the missed quiz. Only the 10 highest-scored quizzes will be counted towards the final grade.

Piazza Discussions

This term we will be using Piazza for class discussion. The system is highly catered to getting you to help fast and efficiently from classmates, the TA, and myself. Rather than emailing questions to the teaching staff, I encourage you to post your questions on Piazza.

Find our class signup link at: https://piazza.com/virginia/spring2023/ds6050residential

For each module, students are encouraged to actively participate in a discussion on the topics covered by the module. You can either create your own post about problems/difficulties you are facing, course-related/broader deep learning questions, interesting ideas, articles/videos you saw on the internet, etc.—almost anything related to the corresponding module. Another way to participate in a discussion is by answering/replying to other people's posts. In any case, please be mindful to be polite, respectful, and helpful.

'Discussion' will be evaluated based on the frequency and the quality of your interactions.

Group Project

The course project will be undertaken as a group project and will be a total of 400 points (or 40% of the final grade) as broken down below:

1. Project proposal & literature review (100 pts)
2. Project checkpoint (data pipeline and model prototypes) (50 pts)
3. Project presentation (100 pts)
4. Project report (150 pts)

Details of the groups are:

- The required group size is three. Individuals may be able to work by themselves with good reason. Expectations will not be adjusted due to the smaller group size. Groups of more than three are strongly discouraged but can be allowed under extreme circumstances. Expectations for groups of four are higher than those for groups of three.
- In general, all group members will receive the same grade for graded assignments. However, group members will evaluate their peers, and any student who appears to not be contributing may be penalized.
- Each group will be responsible for assigning tasks to its group members.
- You are expected to work as a member of your group in this course and cooperate with your colleagues. There will be multiple working sessions and checkpoints to help your team to stay on track with the project. Cooperation means attending group meetings, completing your assignments properly and on time, letting your group know if you will be out of town, responding to emails from your group, and so on. If there is a lack of cooperation by any group member, it must be brought to the attention of the instructor as soon as it happens. If the lack of cooperation is serious, the offending group member's semester grade will be penalized

Electronic Submission of Assignments

All assignments must be submitted electronically through UVACanvas by the specified due dates and times. It is crucial to complete all assigned work—failure to do so will likely result in failing the class.

For late assignments, 10% of the total grade will be deducted per day, where the day means 11:59 p.m. Eastern time cutoff. After three late days, it will be marked as 0 points.

UVA Canvas & Access to Online Course Materials

This course will use an accompanying course site in UVACanvas.

Access Our Course in UVACanvas:

Log in to UVACanvas using your NetBadge credentials. (Need help with NetBadge?)

Getting Started:

- **New to Canvas?** Learn the basics in this 3.5-minute tutorial video.
- **A mobile app is available**. Visit the App Store or Google Play and search for Canvas Student. To connect your app to UVA Canvas, tap "Find my School" and search for "University of Virginia (UVA)." With the Canvas mobile app, you can quickly view grades and announcements and send messages.
    - *Please do not use the mobile app for taking quizzes and tests.
- **Know how to get UVACanvas help.**
  Students have access to 24/7 support from Canvas. Get help using one of the following options:
    - Log in to UVACanvas and click Help in the main navigation
    - Search the Canvas Guides (Step-by-step instructions)
    - 24/7 Chat with Canvas Support
    - 24/7 Canvas Support Hotline: +1 (866) 897-5086
    - UVACanvas Website

Technical Specifications

Computer Hardware

Operating system: Microsoft Windows 8.1 (64-bit) or Mac OS X 10.10 Minimum hard drive free space: 100 GB, SSD recommended Minimum processor speed: Intel 4th Gen Core i5 or faster. RAM: 4 GB

UVA Policies

SDS Grading Policies

The standing of a graduate student in each course is indicated by one of the following grades: A+, A, A-; B+, B, B-; C+, C, C-; D+, D, D-; F. B- is the lowest satisfactory grade for graduate credit.

Attendance

Students are expected to attend all class sessions. Instructors establish attendance and participation requirements for each of their courses. Class requirements, regardless of delivery mode, are not waived due to a student's absence from class. Instructors will require students to

make up any missed coursework and may deny credit to any student whose absences are excessive. Instructors must keep an attendance record for each student enrolled in the course to document attendance and participation in the class.

University Email Policies

Students are expected to check their official UVA email addresses on a frequent and consistent basis to remain informed of university communications, as certain communications may be time sensitive. Students who fail to check their email on a regular basis are responsible for any resulting consequences.

Mid-Term and End-of-Class Evaluations

Students may be expected to participate in an online mid-term evaluation. Students are expected to complete the online end-of-class evaluation. As the semester comes to a close, students will receive an email with instructions for completing this. Student feedback will be very valuable to the school, the instructor, and future students. We ask that all students please complete these evaluations in a timely manner. Please be assured that the information you submit online will be anonymous and kept confidential.

University of Virginia Honor System

All work should be pledged in the spirit of the Honor System at the University of Virginia. The instructor will indicate which assignments and activities are to be done individually and which permit collaboration. The following pledge should be written out at the end of all quizzes, examinations, individual assignments, and papers: "I pledge that I have neither given nor received help on this examination (quiz, assignment, etc.)." The pledge must be signed by the student. For more information, visit www.virginia.edu/honor.

Special Needs

It is my goal to create a learning experience that is as accessible as possible. If you anticipate any issues related to the format, materials, or requirements of this course, please meet with me outside of class so we can explore potential options. Students with disabilities may also wish to work with the Student Disability Access Center to discuss a range of options to removing barriers in this course, including official accommodations. Please visit their website for information on this process and to apply for services online: https://sdac.studenthealth.virginia.edu. If you have already been approved for accommodations through SDAC, please send me your accommodation letter and meet with me so we can develop an implementation plan together.

About This Syllabus

This syllabus is to be considered a reference document that can and will be adjusted through the course of the semester to address changing needs. It is up to the student to monitor this page for any changes, as this syllabus can be changed without notification. The final authority on any decision in this course rests with the course instructor, not with this document.