SMATH-470: Introduction to Deep Learning with Python

1. General Information

Instructor	Dr. Erdi KARA
Email	erdikara@spelman.edu
Time/Venue	MWF 2:00-2:50pm, Tapley-313
Office Hours	M-11:00-11:50 am, F-09:00-10:00 am
Office	Tapley-310
Zoom for office hours	-
Zoom for classes	-
Github	Course Github Page
Slack Channel	-

I would like to acknowledge AUC Data Initiative for their support in the creation of this class. I would also like to thank Microsoft's machine learning experts Anushka Madwesh, Kem Ezoeke, Mark Gazai, Nolen Code, Taisha Ferguson for providing excellent mentorship to students in this class throughout the semester and working with them on amazing projects. Finally, I would like to thank Microsoft for providing a Microsoft Azure Sponsorship as a cloud computing resource.

Course Description: This course is designed to provide a comprehensive introduction to deep learning, a powerful machine learning technique that has revolutionized many fields including computer vision, natural language processing, and speech recognition.

Students will learn about the fundamental concepts and techniques used in deep learning, including neural networks, convolutional neural networks and transfer learning. They will also learn about various optimization algorithms, such as

stochastic gradient descent, and how to use these algorithms to train deep learning models on large datasets.

In addition to the theoretical foundations of deep learning, students will also have the opportunity to apply their knowledge through hands-on coding exercises and projects. These projects will involve using Pytorch, a cutting-edge deep learning Python framework, to build and train deep learning models on real-world datasets.

Throughout the course, students will gain a deep understanding of how deep learning works and work on hands-on projects to apply their knowledge and skills to real-world data sets. This course is ideal for students with some programming experience who are interested in exploring the exciting world of machine learning and artificial intelligence. Students will also have the opportunity to meet machine learning practitioners in several talks to be organized in the scope of the course.

In addition, teams of two students will be formed at the beginning of the semester each and each group will be assigned to a data science expert from Microsoft. Under the supervision of the group mentor, groups will identify machine learning and data science related projects.

The project outcomes will be posted on GitHub so that students can showcase their work in their professional applications.

Prerequisites: MATH 214, MATH 232, **CS113.** Familiarity with Python is essential for this class.
Fourth Hour Justification: This course has three 50-minute meetings per week, which corresponds to three semester credit hours. The fourth credit hour is given for special work done outside the classroom. This may include individual/group projects assignments using Python as well as collecting and cleaning data those assignments.

Purpose of the Course: This course aims to introduce the fundamental concepts of deep learning and its applications in computer vision.

Goals and Objectives: This course will introduce the student to the mathematical foundations of neural networks and their practical implementations in several real life applications.

Learning Outcomes: Upon successful completion of this course, the student should be able to

- ➢ Describe what types of problems can be solved using supervised machine learning techniques
- ➢ Identify applications which can be analyzed using neural networks.
- ➢ Use Python libraries such as Numpy, Pandas, and Matplotlib to conduct exploratory data analysis and gain insights from data
- ➢ Build and train linear regression models using Skilearn machine learning framework.
- ➢ Create and train neural networks using *Pytorch* library.
- ➢ Understand the hyperparameter optimization process .
- ➢ Explore the potential of transfer learning and incorporate the-state-of-the-art deep learning architectures into their own applications.
- ➢ Evaluate the performance of neural network models using performance metrics.
- ➢ Assess the performance of neural network models using performance metrics, and create and present a comprehensive modeling pipeline for image recognition applications using cloud computing on Microsoft Azure or Google Colab

2. Resources and Tools

Our main objective in this class is to build deep learning models using the Pytorch framework. We will mainly focus on computer vision applications. The following book by Ian Pointer is an excellent introduction to Pytorch. A PDF version of the book is available online. In addition, We will also utilize two online resources from Tomas Beuzen and Daniel Bourke.

Programming PyTorch for Deep Learning: Creating and Deploying Deep Learning Applications, 1st Edition, Ian Pointer.

- ➢ *Deep Learning with PyTorch by Tomas Beuzen*

- ➢ *Pytorch Zero to Mastery by Daniel Bourke*

You can also consult to resources below;

- ➢ *Deep Learning, Ian Goodfellow, Yoshua Bengio and Aaron Courville.*
- ➢ *PyTorch Pocket Reference: Building and Deploying Deep Learning Models*, 1st Edition, Joe Papa.

➢ *Machine Learning with PyTorch and Scikit-Learn: Develop machine learning and deep learning models with Python*, Sebastian Raschka , Yuxi (Hayden) Liu , Vahid Mirjalili.
PyTorch Computer Vision Cookbook, Michael Avendi

Online tutorials are an essential part of the learning process in machine learning. I have provided a list of useful resources here. These resources will be referred to during the semester, and I encourage you to click on them and subscribe to Youtube channels. Keep in mind that some of our assignments will be based on these tutorials.

➢ Python Programming Lecture by Corey Schafer

➢ Deep Learning Fundamentals
- Introduction to Neural Networks by Deep Lizard
- Neural Networks by 3Blue1Brown
- NYU Deep Learning SP20

➢ Pytorch Tutorials
Python Engineer
Deep Lizard

Jupyter, Google Colab and Microsoft Azure

➢ Python is the mainstream programming language for machine learning. There are several ways you can install Python locally to your computer. Simply use Anaconda to install Python using the tutorial here. We will write our codes using Jupyter. The same tutorial will also help you to get started with Jupyter notebooks. Jupyter has mainly two nice interfaces, Jupyter notebook and Jupyter Lab. They are pretty much the same but we will be using the Jupyter Lab since it has a more compact structure. You can watch the short tutorial here to get familiar with it.

➢ To maintain uniformity among all computing environments, I will post all of our lecture notes, assignments, codes etc on Google Colab. This will allow us to write and execute our Python codes through our browser using Google's cloud computing resources. Moreover, to train our deep learning models in a reasonable amount of time, we must take advantage of GPU computing. Google Colab will provide you with a pretty powerful GPU for free. Technical details will be discussed in the class so you don't need to

panic. All you need is a Google account. Please watch the tutorial series here to see how it works.

- ➢ *Once the semester starts, we will form our study groups. You will get a link for your group pointing to a folder with your group name. You will find all the materials in this folder and I will keep updating it as we progress in the class. Make sure to put that shared folder in a visible location in your Google drive.*
- ➢ We will also learn Microsoft Azure for our capstone projects. Azure provides a cloud computing environment to create and manage end-to-end machine learning projects. We have a generous grant from Microsoft for our class.
- ➢ *Our main communication tool is Slack*. Please make sure to sign up using the link at the top of this syllabus. All technical questions must be posted there so that other folks can take advantage of that. If the question is a subtle issue, you can DM me there. Whenever necessary, I will address common issues in the Slack.

3. Course Outline

1. Preliminaries
    a. Basics of Machine Learning
    b. Setting the Stage for the Course
2. Essential Python Modules for Machine Learning
    a. Python Basics
    b. Array Operations with Numpy
    c. Data Visualization with Matplotlib
    d. Data Manipulation with Pandas
    e. Basics of Image Processing with PIL
3. Gentle Introduction to Neural Networks
    a. Gradient Descent Algorithm
    b. Multiple Linear Regression
    c. Deep Neural Networks
    d. Performance Metrics for Image Models
4. Building Neural Networks with Pytorch
    a. Introduction to Pytorch
    b. Feed Forward Neural Networks(FNNs)

    c. Convolutional Neural Networks(CNNs)
5. Improving Neural Networks
    a. Transfer Learning
    b. Data Augmentation, Regularization and Ensembling
    c. Hyperparameter Optimization with Optuna
6. Modern Practices(if time permits)
    a. Model Deployment with Gradio
    b. AutoEncoders, Generative Models, Diffusion Models, Transformers
    c. YOLO, GPT3, Stable Diffusion, Whisper
    d. Introduction to Hugging Face Domain
7. Discussion of Capstone Projects

4. Assessment and Grading

Exams	Weight
Capstone Project-1	25%
Capstone Project-2	25%
Assignments	40%
Attendance	10%

Instead of traditional exams, our class will focus on learning through group projects and assignments. Teams of two students will be formed at the beginning of the semester and work on all projects and assignments as a group. The final grade will be determined by the following criteria.

Capstone Project-1

- ➢ Each group will identify a target application that can be addressed using neural networks. Although the course specifically focuses on image recognition, groups can pick up any neural network application that can be completed before the end of semester.
- ➢ I will provide a set of potential applications but groups are encouraged to identify their own projects. Once the target problem is identified, we will create an end-to-end project pipeline and deploy our model publicly.
- ➢ Each group will present their work on the day of the final exam day. This project will make up 25% of the overall grade.

Capstone Project-2

- Each group will be assigned to a data science expert from Microsoft. Under the supervision of the group mentor, groups will identify machine learning and data science related projects.
- Group members should keep in mind their mentor is volunteering part of their precious time to help them. Therefore, it is important to respect your mentor's time and efforts during the semester.
- Group members should be committed to carry out the tasks such as collecting data, doing some research and preparing short presentations assigned by their mentor as part of their projects.
- Each group will present their work by the end of April. This project will make up 25% of the overall grade.

Group Assignments

- There will be one big group assignment after each chapter.Most of the assignments are related to coding implementation of the concepts discussed in the class. A Jupyter notebook template will be completed for each assignment and the submission will be in the form of Jupyter notebooks.
- You are welcome to look up online and use the existing codes by properly citing the resources. However, whenever necessary, each piece of code must include short annotations briefly explaining what the code actually does.
- At the end of each submission(i.e. Jupyter notebook), group members will write a short summary that explains (i) what you contributed to the assignment, (ii) what your partner contributed to the assignment.
- This section will make up 40% of the overall grade.

Attendance

- This class will give students hands-on experience with neural networks, particularly in the field of computer vision. Each section will cover both the theoretical and practical aspects of neural networks, as well as industry standard machine learning and data science tools.
- Therefore, it is absolutely essential to attend all classes consistently. Group members are expected to support each other in case the other member cannot make the class.
- Attendance will make up 10% of the overall grade.

Final Grades:
Final letter grades for the course will be assigned according to the following 100-point scale:

93 – 100 A 90 – 92 A - 87 – 89 B+ 83 – 86 B 80 – 82 B- 75 – 79 C+ 70 – 74 C 67 – 69 C- 63 – 66 D+ 60 – 62 D Below 60 F

Final grades cannot be changed except in the case of a mathematical error.

3. COURSE POLICIES

Calculators, Cell Phones, and Computers: Use of computers in this class is encouraged. However, computers are not to be used for personal reasons including accessing facebook, twitter, email, and the internet, unless use of the internet is class related. **Absolutely no texting in class!! All cell phones must be turned off during the class period.** If a cell phone vibrates or rings during class OR if you are found texting or misusing computers during class, you may be asked to leave class for that day. PLEASE DO NOT argue with me over these situations. If you are asked to leave, JUST LEAVE. You can stop by my office later to explain yourself or make your case!!

Academic Integrity Policy

At the heart of Spelman College's mission is academic excellence, along with the development of intellectual, ethical and leadership qualities. These goals can only flourish in an institutional environment where every member of the College affirms honesty, trust and mutual respect. All members of the academic community of Spelman College are expected to understand and follow the basic standards of honesty and integrity, upholding a commitment to high ethical standards. Students are expected to read and abide by the Spelman College Code of Conduct (see the current Spelman College Handbook) and are expected to behave as mature and responsible members of the Spelman College academic community. Academic dishonesty includes, but is not limited to, cheating, plagiarism, getting help from tutors, other students or professors on graded work, or knowingly helping others to violate the college policy. *Any student caught cheating on a quiz or exam will receive a grade of "0" on that quiz or exam, and the incident will be reported to the Math Department Chairperson and Academic Dean*. Students are expected to follow ethical standards in their personal conduct and in their behavior towards other members of the community. Students are expected to observe basic honesty in their work, words, ideas, and action. Failure to do so is a violation of the Spelman College Academic Integrity Policy. Violators will be subject to the sanctions outlined in the Spelman College Bulletin.

Disability Statement

Spelman College is committed to ensuring the full participation of all students in its programs. If you have a documented disability (or think you may have a

disability) and, as a result, need a reasonable accommodation to participate in class, complete course requirements, or benefit from the College's programs or services, you should contact Student Access Center (SAC) as soon as possible. To receive any academic accommodation, you must be appropriately registered with SAC. The SAC works with students confidentially and does not disclose any disability-related information without their permission. SAC serves as a clearinghouse on disability issues and works in partnership with faculty and all other student service offices. For further information about services for students with disabilities, please contact the SAC at 404-270-5289, located in MacVicar Hall, Room 106.

Testing for Students Needing Accommodations: Any student with a documented disability who needs accommodations to take an exam must give the instructor at least 24-hour notice. Any student with this special need must take the exam during a time that overlaps with the regular test time, and is not permitted to take the exam at two different times.

Additional Help

Students are strongly encouraged to attend office hours and make outside appointments if necessary. For additional assistance, free tutorial help is available in the Mathematics Laboratory located on the 3rd floor of Tapley Hall, in room 301. Check the hours of operation on the door of Tapley 301.

4. Special Syllabus Statement on COVID-19

Spelman College recognizes that this is a difficult time which may be filled with uncertainty as we move forward with the 2021-2022 academic year. Your safety, health, and well-being, as
well as that of our faculty and staff are our primary concern and we want to be able to support you in any way that we can. We ask that you adjust your behavior to keep yourself and others safe. The College has expectations that students, faculty and staff will act responsibly to mitigate risk to others.

Face Mask/Covering in the Classroom is required.

In accordance with Spelman College and the Atlanta University Center Consortium (AUCC) Covid protocols, all vaccinated and unvaccinated individuals are required to wear face masks/covering in classrooms, laboratories, and other public space where in-person instruction occurs. Facemasks/coverings must cover the nose and mouth and fit snugly against the face. Face shields do NOT replace mask wearing.

Failure to comply with Spelman College protocols for face masks/coverings will constitute a violation of the Spelman College Code of Conduct. If you are not wearing a face covering, you will be asked to do so. Refusal to wear a face mask/covering will result in your being asked to leave the classroom. Please note that while exceptions for medical reasons will be accommodated to the best of the College's ability, the College cannot provide an accommodation that places others at risk; therefore, an accommodation to participate in class or related activities in person without a face covering will not be permitted.

Safe Behavior in the Classroom

Physical distancing of at least six feet, will be observed whenever possible. Any student experiencing symptoms of COVID-19, with a suspected or positive diagnosis of COVID-19, or with known exposure to COVID-19 should not attend class or come to campus, if not a residential student. Students who are experiencing symptoms or believe they may have been exposed to COVID-19 should call Student Health Services or their health care provider for guidance. Any student with a positive diagnosis of COVID-19 or with known exposure to COVID-19 must report this fact to Student Health Services at 404-270-5249. COVID-related class absences fall under the College's excused absence policy. Per the College's COVID protocols, a student who becomes ill or is required to quarantine during the semester should notify the Office of Undergraduate Studies for an excused absence.