STATS 403

Deep Learning

2024-25 Spring Session 4

Days/meeting time:

- Lecture: MoWe 8:30am-11am @ WDR 1007

Academic credit: 4 units

Instructor's Information

Dongmian Zou, Assistant Professor of Data Science

Email: dongmian.zou@dukekunshan.edu.cn

Office hour: Mo 11am-noon, or by appointment @ WDR 3010

Dongmian Zou has a B.Sc. in Mathematics from the Chinese University of Hong Kong (2012) and a Ph.D. in Applied Mathematics from the University of Maryland, College Park (2017). Before joining Duke Kunshan, he served as a postdoctoral researcher at the University of Minnesota, Twin Cities from 2017 to 2020.

Dongmian is interested in mathematical aspects of data science. His primary research is in the intersection among applied harmonic analysis, machine learning and signal processing. Specifically, He is focusing on robust representations and structures in geometric and graph deep learning.

Dongmian loves cats, and he is better than any machine learning algorithms at distinguishing cats from dogs.

Grader: Xue Chen

- Email: xue.chen240@dukekunshan.edu.cn

What is this course about?

Learning requires experience. In order to learn complicated concepts, a computer needs to build hierarchy of concepts. If we draw a graph showing how these concepts are built on top of each other, the graph is deep. This approach, known as deep learning, has gained much attention, become increasingly popular, and achieved tremendous successes in data science. Most deep learning architectures are based on artificial neural networks, especially convolutional neural networks (CNN's) and recurrent neural networks (RNN's). They are effective models for high-dimensional data, especially images, text and audio data. This course serves as an introduction to deep learning. We will cover a range of topics on neural networks including multi-layer perceptron, CNN and RNN, and generative networks. We will also study the

mathematical and statistical views of neural networks in order to understand how they approximate and generate. Further, we will look at deep learning applications for speech, image, video, etc.

What background knowledge do I need before taking this course?

Prerequisite: Machine Learning (at the level of STATS302/COMPSCI309/MATH405, which indicates a good background in calculus, linear algebra, probability and coding).

What will I learn in this course?

By the end of this course, you will be able to:

- comprehend the fundamentals of deep learning
- design, train and implement neural network models
- understand the mathematical, statistical, and computational issues of deep learning
- touch the state-of-the-art solutions to practical applications

What will I do in this course?

- **lectures**
- **homework assignments:** 2 HWs in total. The problems in the homework can be mathematical, conceptual, or coding-related. You are encouraged to discuss among yourselves and consult with me for the homework, but you must write up the solution by yourself.
- **exams**: 1 take-home final exam.
- **course project:** 1 course project. You will carefully study a topic related to deep learning, which can be an application, algorithmic or theoretical problem related to computer vision, natural language processing, generative modeling, reinforcement learning, etc. Your deliverables include a proposal at the beginning of the session as well as a report and a presentation at the end of the session. You are free to choose the topic and reference papers.

What required texts, materials, and equipment will I need?

- *Lecture Notes in Deep Learning* by Dubnov & Zou (The book is not published yet, so a draft book will be shared)

What optional texts or resources might be helpful?

- *Deep Learning : Foundations and Concepts* by Bishop & Bishop (https://find.library.duke.edu/catalog/DUKE99119493924008501)

How will my grade be determined?

Activity	Points	Comments
Homework	40%	submit on Canvas; 2 in total
Exam	20%	submit in person; take-home exam

Project	30%	proposal + paper + presentation
Participation	10%	class participation

Please refer to the following scale for your grading.

A+= 98% - 100%; A = 97% - 93%; A- = 90% - 92%;
B+ = 87% - 89%; B = 83% - 86%; B- = 80% - 82%;
C+ = 77% - 79%; C = 73% - 76%; C- = 70% - 72%;
D+ = 67% - 69%; D = 63% - 66%; D- = 60% - 62%; F = 59% and below

What are the course policies?

Communications:

- Course materials and announcements will be posted on Canvas regularly.
- The best way to reach me is via email (I check and respond to emails regularly).

Discussion Guidelines:

Civility is an essential ingredient for academic discourse. All communications for this course should be conducted constructively, civilly, and respectfully. Differences in beliefs, opinions, and approaches are to be expected. Please bring any communications you believe to be in violation of this class policy to the attention of your instructor. Active interaction with peers and your instructor is essential to success in this course, paying particular attention to the following:

- Be respectful of others and their opinions, valuing diversity in backgrounds, abilities, and experiences.
- Challenging the ideas held by others is an integral aspect of critical thinking and the academic process. Please word your responses carefully, and recognize that others are expected to challenge your ideas. A positive atmosphere of healthy debate is encouraged.
- Read your online discussion posts carefully before submitting them.

Academic Integrity:

As a student, you should abide by the academic honesty standard of Duke Kunshan University. The DKU Community Standard states: “Duke Kunshan University is a community comprised of individuals from diverse cultures and backgrounds. We are dedicated to scholarship, leadership, and service and to the principles of honesty, fairness, respect, and accountability. Members of this community commit to reflecting upon and upholding these principles in all academic and non-academic endeavors, and to protecting and promoting a culture of integrity and trust.” For all graded work, students should pledge that they have neither given nor received any unacknowledged aid.

There is zero tolerance to cheating. You will not get credits from cheating. Any instances of cheating will result in receiving no credit for the assignment or exam, and may lead to further disciplinary actions.

Academic Policy & Procedures:

You are responsible for knowing and adhering to academic policy and procedures as published in the University Bulletin and Student Handbook. Please note, an incident of behavioral infraction or academic dishonesty (cheating on a test, plagiarizing, use of online tools prohibited by the instructor at the course or assignment level, etc.) will result in immediate action from me, in consultation with university administration (e.g., Dean or Associate Dean of Undergraduate Studies, Student Conduct, Academic Advising). Please visit the Undergraduate Studies website for additional guidance related to academic policy and procedures. Academic integrity is everyone's responsibility.

Academic Disruptive Behavior and Community Standard:

Please avoid all forms of disruptive behavior, including but not limited to: verbal or physical threats, repeated obscenities, unreasonable interference with class discussion, making/receiving personal phone calls, text messages or pages during class, excessive tardiness, leaving and entering class frequently without notice of illness or other extenuating circumstances, and persisting in disruptive personal conversations with other class members. Please turn off phones, pagers, etc. during class unless instructed otherwise. Laptop computers may be used for class activities allowed by the instructor during synchronous sessions. If you choose not to adhere to these standards, I will take action in consultation with university administration (e.g., Dean of Undergraduate Studies, Student Conduct, Academic Advising).

Academic Accommodations:

Duke Kunshan University makes reasonable academic accommodations for qualified students with disabilities. All undergraduate accommodations must be approved through the Student Accommodation Services. Students requesting accommodations for this course should forward their official accommodation letter to the instructor and ask to schedule a time to meet and discuss the implementation of their accommodation(s). It is the student's responsibility to meet, discuss, and provide an electronic copy of the Instructor Accommodation Letter to each instructor. Accommodations will not be granted retroactively. Accommodations for test, quiz, or exam taking must be arranged with the professor at least a week before the date of the quiz, test or exam, including finals.

What campus resources can help me during this course?

Academic Advising and Student Support

Please consult with me about appropriate course preparation and readiness strategies, as needed. Consult your academic advisors on course performance (i.e., poor grades) and academic decisions (e.g., course changes, incompletes, withdrawals) to ensure you stay on track with degree and graduation requirements. In addition to advisors, staff in the Academic Resource Center can provide recommendations on academic success strategies (e.g., tutoring, coaching, student learning preferences). Please visit the Office of Undergraduate Advising website for additional information related to academic advising and student support services.

Writing and Language Studio

For additional help with academic writing—and more generally with language learning—you are welcome to make an appointment with the Writing and Language Studio (WLS). You can register for an account, make an appointment, and learn more about WLS services, policies, and events on the WLS website. You can also find writing and language learning resources on the Writing & Language Studio Sakai site.

IT Support

If you are experiencing technical difficulties, please contact IT:

- China-based faculty/staff/students 400-816-7100, (+86) 0512- 3665-7100
- US-based faculty/staff/students (+1) 919-660-1810
- International-based faculty/staff/students can use either telephone option (recommend using tools like Skype calling)
- Live Chat: https://oit.duke.edu/help
- Email: service-desk@dukekunshan.edu.cn

What is the expected course schedule?

date	class topic / unit name	assignments due

week 1	• neural network basics
	  ○ introduction
	  ○ neural networks (NN)
	  ○ optimization	

week 2	• representation learning
	  ○ autoencoder (AE)
	  ○ variational autoencoder (VAE)
	  ○ ELBO
	• project proposal presentation	

week 3	• convolution and transformer
	  ○ convolutional neural networks (CNN)
	  ○ recurrent neural networks (RNN)
	  ○ self-attention (SA) and transformers	

week 4	• generative models
	  ○ generative adversarial networks (GAN)
	  ○ normalizing flows
	  ○ diffusion models
		HW1

week 5	• deep understanding
	  ○ information theory
	  ○ gaussian processes (GP)
	  ○ neural tangent kernels (NTK)	

week 6	• further topics
	  ○ transfer learning (TL)
	  ○ explainable AI (XAI)
	  ○ reinforcement learning (RL)
		HW2

week 7	• presentations	
final week		final exam; project report