Lahore University of Management Sciences

EE 414/517, CS 437/5317: Deep Learning

Fall 2024

Personnel Details	
Lead Instructor	**Hassan Mohy-ud-Din, PhD**
Room No. and Phone	9-246, SBASSE Tesla Wing. Telephone Extension: 8505.
Office Hours	**Hassan:** appointment by email (hassan.mohyuddin@lums.edu.pk)
Co-Instructors	**TBA** (), **TBA** (), **TBA** (), and **TBA** ()
Co-Instructors' Office Hours	**TBA:** (), **TBA:** (), **TBA:** (), and **TBA:** ()
Course URL	LMS Site
Support Services	LUMS offers a range of academic and other services to support students. These are mentioned below, and you are encouraged to use these in addition to in-class assistance from course staff. For a complete list of campus support services available for you click here: https://advising.lums.edu.pk/#supportservices

Course Offering Details					
Credit Hours	3				
Classes (per week)	2	Duration	75 min each	Timings & Venue	Tuesday & Thursday, 11:30 AM – 12.45 PM, SBASSE TBA

Course Teaching Methodology				
Main Lectures	Mode	On-campus lectures	Duration (per week)	75 minutes
Supplementary Lectures/Tutorials	Mode	Pre-recorded videos	Duration (occasionally)	Varied
Additional Problem-solving Sessions	Mode	In-office OR Zoom	Duration (per week)	Varied

Course Distribution	
Credit Hours	3
Core	-
Elective	Electrical Engineering, Mathematics, Computer Science
Open for Student Category	• MS and PhD students **OR** • CS200/EE201 (Introduction to Programming) **AND** MATH120/Math120H/Math 121 (Linear Algebra) **OR** • PHY 505 (Computational Physics) **AND** MATH120/Math120H/Math 121 (Linear Algebra)

Course Description
Deep Learning has created a revolution in the past decade with numerous applications in science and engineering. A deep learning framework consists of a neural network (architecture) that imitates (very coarsely) the learning process of human beings. A deep neural network can either be trained on sufficiently annotated examples (aka supervised learning) or annotation-free examples (aka unsupervised learning) with the goal that the trained model generalizes well to unseen data. Deep learning has a strong mathematical and practical component that drives this learning framework in almost all applications. In this course, students will learn the basic theory and applications of deep neural networks with a special focus on supervised and unsupervised learning with convolutional neural networks, ensemble learning, transfer learning, autoencoders, GANs, and knowledge distillation. Students will learn to train deep neural networks in PyTorch for various applications in computer vision and medical imaging.

Course Prerequisite(s)/Co-Requisite(s)	
Pre-requisites	• CS200/EE201 (Introduction to Programming) **AND** MATH120/Math120H/Math 121 (Linear Algebra) **OR** • PHY 505 (Computational Physics) **AND** MATH120/Math120H/Math 121 (Linear Algebra)
Recommended	EE 514 or CS 535 (Machine Learning), Python (basic understanding)

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Assessed Course Learning Outcomes	
	The students should be able to:
CLO1:	Understand the (new) paradigm of data-driven learning.
CLO2:	Learn the basic theory and applications of deep learning.
CLO3:	Understand various aspects of training a deep neural network including initialization, batch size, learning rate, optimizer, loss function, regularization, data augmentation, etc.
CLO4:	Learn to perform supervised and unsupervised deep learning in PyTorch.
CLO5:	Understand advanced concepts of deep learning including ensemble learning, autoencoders, GANs, and knowledge distillation, etc.

Relation to EE Program Outcomes

EE-414 CLOs	Related PLOs	Levels of Learning	Teaching Methods	CLO Attainment checked in
CLO1	PLO2	Cog1, Cog2	Instruction, Homework	Assignments/Quizzes/Exam
CLO2	PLO2	Cog1, Cog2	Instruction, Homework	Assignments/Quizzes/Exam
CLO3	PLO2	Cog1, Cog2	Instruction, Homework	Assignments/Quizzes/Exam
CLO4	PLO3	Cog3	Instruction, Homework	Assignments
CLO5	PLO3	Cog3	Instruction, Homework	Assignments/Quizzes/Exam

Grading Breakup and Policy		
Assignments	45%	N-1 policy on assignments. No late submissions are acceptable.
Quizzes	25%	N-2 policy on quizzes. Can be announced or unannounced. No retakes will be allowed.
Exam	30%	Combined and closed book.

Examination Detail	
Exam	**Yes/No:** Yes **Combine/Separate:** combined **Duration:** 3 hours **Preferred Date:** second half of the semester **Exam Specifications:** closed book, closed notes, no help sheets, all relevant formulas will be provided in the question paper.

Campus Support and Key University Policies

Campus Supports

Students are strongly encouraged to meet course instructors and TA's during office hours for assistance in course-content, understand the course's expectations from enrolled students, etc. Beyond the course, students are also encouraged to use a variety of other resources. (Instructors are also encouraged to refer students to these resources when needed.) These resources include Counseling and Psychological Services/CAPS (for mental health), LUMS Medical Center/LMC (for physical health), Office of Accessibility & Inclusion/ OAI (for long-term disabilities), advising staff dedicated to supporting and guiding students in each school, online resources, etc. To view all support services, their specific role as well as contact information click here.

Academic Honesty/Plagiarism

LUMS has zero tolerance for academic dishonesty. Students are responsible for upholding academic integrity. If unsure, refer to the student handbook and consult with instructors/teaching assistants. To check for plagiarism before essay submission, use similarity@lums.edu.pk. Consult the following resources: 1) Academic and Intellectual Integrity and 2) Understanding and Avoiding Plagiarism.

LUMS Academic Accommodations/Petitions Policy

Long-term medical conditions are accommodated through the Office of Accessibility & Inclusion (OAI). Short-term emergencies that impact studies are either handled by the course instructor or Student Support Services (SSS). For more information, please see Missed Instrument or "Petition" FAQs for students and faculty at https://rb.gy/8sj1h.

LUMS Sexual Harassment Policy

LUMS and this class are a harassment-free zone. No behavior that makes someone uncomfortable or negatively impacts the class or individual's potential will be tolerated. To report sexual harassment experienced or observed in class, please contact me. For further support or to file a complaint, contact OAI at oai@lums.edu.pk or harassment@lums.edu.pk. You may choose to file an informal or formal complaint to put an end to

the offending behavior. You can also call their Anti-Harassment helpline at 042-35608877 for advice or concerns. For more information: *Harassment, Bullying & Other Interpersonal Misconduct: Presentation*.

SSE Council on Equity and Belonging

In addition to LUMS resources, SSE's Council on Belonging and Equity is committed to devising ways to provide a safe, inclusive and respectful learning environment for students, faculty and staff. To seek counsel related to any issues, please feel free to approach either a member of the council or email at cbe.sse@lums.edu.pk.

Rights and Code of Conduct for Online Teaching

The misuse of online modes of communication is unacceptable. TAs and Faculty will seek consent before the recording of live online lectures or tutorials. Please ensure, if you do not wish to be recorded during a session to inform the faculty member. Please also ensure that you prioritize formal means of communication (email, LMS) over informal means to communicate with course staff. Kindly follow the copyright rules attached with the educational materials uploaded on LMS by the instructor.

Course Overview

Week No.	Reference Readings	Topic	Related CLOs
1	Reading Assignment # 1 Tutorial # 1 Assignment # 0	**Introduction with Applications** We will cover the following topics: • Real-world applications from numerous domains. • Why *Learning* is essential? • What is Artificial Intelligence, Machine Learning, and Deep Learning? • *Learning* vs *Inference* – Overfitting and Generalization • Types of Learning: Fully Supervised, Unsupervised, Semi-supervised, Self-Supervised, and Reinforcement Learning. • Regression vs Classification. • ChatGPT and Large Language Models • What is Intelligence? Noam Chomsky's perspective on intelligence • The anticipated world out of AI • Embracing AI or Resisting AI – Role of Natural Selection • Explainability, Interpretability, Reproducibility, and Replicability	CLO1
2 – 3	Reading Assignment # 2 Tutorial # 2	**Gradient-based Optimization** We will cover the following topics: • Review of Vector Calculus. • Optimization. • First-order optimization method. • Learning formulated as an optimization problem. • The problem of parameter estimation. • Variants of first-order methods including Stochastic Gradient Descent (SGD). • Loss functions: Topology, Optimal solution, Convexity, etc. • Flat minima and generalizability.	CLO3
	Reading Assignment # 2 Tutorial # 2 Assignment # 1	**First-order Optimization Algorithms** We will talk about several variants of SGD including: • Momentum method. • Nesterov accelerated gradient method. • Adam method. • Learning rate policies	CLO3
4 – 5	Reading Assignment # 3 Tutorial # 3 and Tutorial # 4 Assignment # 2	**Deep Learning – A Modern Learning Paradigm** We will talk about: • Learning Methodology – Conventional vs Modern Paradigm • Human visual system – An inspiration • A brief timeline of Deep Learning.	CLO2

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		• Perceptron and Multi-layered Perceptron model. • When is Learning possible? • (Multi-layered) Sigmoid neuron model. • Neural network architecture and MNIST problem. • Backpropagation • Limitation of sigmoid neuron models	
6 – 7	Reading Assignment # 4 Tutorial # 5 Assignment # 3	**Aspects of Neural Network** We will focus on the following aspects: • Activation functions. • Vanishing gradient problem and exploding gradient problem. • Initialization schemes. • Overfitting, underfitting, and reasonable fitting in deep neural networks. • Regularization includes L_1 and L_2 weight decay, dropout, data augmentation, and early stopping. • Implicit vs Explicit Regularization. • Bias-Variance trade-off, Model complexity, and Training-Validation performance trade-off. • Batch size.	CLO3
8 – 9	Reading Assignment # 5 Tutorial # 6 Assignment # 4	**Convolutional Neural Network** We will cover in-depth the mathematical structure of convolutional neural network. We will also study the following important modules: • Batch normalization • Convolutional filters • Activation units • Pooling	CLO2, CLO3, CLO4
10 – 14	Reading Assignment # 6 and Reading Assignment # 7 Tutorial # 7 and Tutorial # 8 Assignment # 5, Assignment # 6, and Assignment # 7	**Advanced Topics in Deep Learning** We will study the following topics: • Autoencoders • GANs • Knowledge Distillation • Contrastive Learning • Diffusion Models • Transformers	CLO5

Textbook(s)/Supplementary Readings

Books on Deep Learning:

- Christopher M. Bishop and Hugh Bishop, **Deep Learning: Foundations and Concepts**, Springer (2024). [Ebook]
- Simon J. D. Prince, **Understanding Deep Learning**, MIT Press, (2024). [Ebook]
- Francois Fleuret, **The Little Book of Deep Learning**, Creative Commons, (2023). [Ebook]
- Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola, **Dive into Deep Learning**, arXiv, (2021). [Ebook]
- Pradeepta Mishra, **PyTorch Recipes**, Apress, Springer, (2019). [Ebook]
- Sandro Skansi, **Introduction to Deep Learning**, Springer (2018). [Ebook]
- Charu C. Aggarwal, **Neural Networks and Deep Learning**, Springer International Publishing, (2018). [Ebook]
- Francois Chollet, **Deep Learning with Python**, Manning Publications, (2018).
- Antonia Gulli and Sujit Pal, **Deep Learning with Keras**, Packt Publishing Ltd, (2017).
- Nikhil Ketkar, **Deep Learning with Python: A hands-on introduction**, APress, (2017). [Ebook]
- Nikhil Buduma and Nicholas Lacascio, **Fundamentals of Deep Learning: Designing next-generation machine intelligence algorithms**, O'Reilly Media, Inc., (2017). [Weblink]
- Phil Kim, **MATLAB deep learning – With Machine Learning, Neural Networks and Artificial Intelligence**, Springer, (2017). [Ebook]
- Ian Goodfellow, Yoshua Bengio, Aaron Courville, **Deep Learning**, MIT Press, (2016). [Ebook]
- Michael Nielsen, **Neural Networks and Deep Learning**, Determination press, (2015). [Ebook]

Books on Optimization:

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- Jorge Nocedal and Stephen Wright, **Numerical Optimization**, Springer Science & Business Media, (2006).
- Stephen P. Boyd and Lieven Vandenberghe, **Convex Optimization**, Cambridge University Press, (2004). [Ebook]
- Dimitri P. Bertsekas, **Nonlinear Programming**, Athena Scientific, (1999).

Prepared and revised by:	**Dr. Hassan Mohy-ud-Din**
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