Lahore University of Management Sciences

CS 437/CS 5317/EE 414/EE 517 – Deep Learning

Spring 2024

Subject to Change

Course Description
Deep Learning is a hierarchical learning methodology based on artificial neural networks which are algorithms inspired by the structure and function of the brain. It has applications in wide-range of industries these days such as face-recognizers working at massive scales, robotics, speech translation, text analysis, improving customer experience, autonomous vehicles etc. In this course we will take a "hands-on approach" and start will implementation of basic building blocks such as training a simple perceptron and move to design and train a deep convolution neural network. Course will concentrate in developing both mathematical knowledge and implementation capabilities. The implementations will be python based using TensorFlow, PyTorch and Keras. After establishing our foundation in convolutional neural networks we will start looking into applications of deep learning in both spatial as well as time-series data and explore various network architectures suited for each. The objective is to help you build a career in AI and ML, to make you comfortable enough that you can understand various learning problems and develop your own deep learning based solutions.

Course Distribution	
Core	No
Elective	Yes
Open for Student Category	Graduate OR CS 200 and Math 120 OR Phy 505 and Math 120
Close for Student Category	Freshman

COURSE PREREQUISITE(S)	
•	CS 200 - Introduction to Programming OR Phy 505 – Computational Physics
•	Math 120 – Linear Algebra with Differential Equations

Course Offering Details				
Credit Hours	3			
Lecture(s)	Nbr of Lec(s) Per Week	2 (MonWed)	Duration	75 min (11:00 – 12:15 pm)
Recitation/Lab (per week)	Nbr of Lec(s) Per Week	0	Duration	N/A
Tutorial (per week)	Nbr of Lec(s) Per Week	1 (Fri)	Duration	45 min (offline/recorded)

Instructor	Murtaza Taj	**Telephone**	3301
Room No.	9-G11A	**Secretary/TA**	TBA
Office Hours	TBA	**TA Office Hours**	TBA
Email	murtaza.taj@lums.edu.pk	**Course URL (if any)**	LMS

Course Teaching Methodology

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Teaching Methodology	Synchronous online with recordings of zoom sessions and offline supplementary lectures
Lecture Details	100% live interactions (recordings will also be available via LMS and Youtube)

Class Discussion Forum on Piazza
This term we will be using Slack for class discussion. The system is highly catered to getting you 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 relevant channel on slack.

PROGRAM EDUCATIONAL OBJECTIVES	
PEO-01	Demonstrate excellence in profession through in-depth knowledge and skills in the field of Computing.
PEO-02	Engage in continuous professional development and exhibit quest for learning and achieve leadership.
PEO-03	Show professional integrity and commitment to societal responsibilities.

COURSE OBJECTIVES	
CO-01	Motivate the class about data driven problem solving paradigm
CO-02	Introduce the basic theory and applications of Deep Learning
CO-03	Provide a solid foundation for further work in this area both in academia and industry

Course Learning Outcomes	
CLO-01 CLO-02 CLO-03 CLO-04 CLO-05 CLO-06	At the successful completion of the course students will be able to: (Compare, Develop, Engage, Analyze, Discuss, Demonstrate…) • Enabling Knowledge: (C1) ***use*** python to ***code*** neural network and convolutional neural network architectures using frameworks such as tensorflow, keras, pytorch etc. • Critical Thinking and Analysis: (C4) ***analyze*** the requirements for solving complex machine learning problems. • Problem Solving: (C6) ***design*** and ***implement*** convolutional neural network (CNN) architectures to solve real-world problems via machines learning, based on analysis of the requirements. (C5) ***evaluate*** the correctness of the proposed solution. • Communication: (C2) ***explain*** key concepts of CNN architecture design in written form. • Responsibility: (C3) ***apply*** relevant standards and ethical considerations to machine learning.

CLO	**CLO Statement**	**Bloom's Cognitive Level**	**PLOs/Graduate Attributes (Seoul Accord)**
CLO1	***use*** python to ***code*** neural network and convolutional neural network architectures using frameworks such as tensorflow, keras, pytorch etc	C1	PLO3

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CLO2	***analyze*** the requirements for solving complex machine learning problems.	C4	PLO2
CLO3	***design*** and ***implement*** convolutional neural network (CNN) architectures to solve real-world problems via machines learning, based on analysis of the requirements	C6	PLO3
CLO4	***evaluate*** the correctness of the proposed solution	C5	PLO4
CLO5	***explain*** key concepts of CNN architecture design in written form	C2	PLO7
CL06	***apply*** relevant standards and ethical considerations to machine learning	C3	PLO5, PLO9

Grading Breakup and Policy

Assessment	Description	Weight (%)	Related CLOs	ACM Recommended Disposition
Quizzes	There will be 8 to 10 quizzes. Two will be dropped	15%	CLO1, CLO2	D4, D7, D9
Programming Assignments	Upto 6 programming assignments will be given, one after every two weeks	40%	CLO2, CLO3, CLO5	D3, D4, D7, D9
Mid Term Exam	One mid-term exams will be conducted. Duration: 50~90 mins (May vary if taken online) Preferred Date: 14th Lecture Exam Specifications: Closed book, No calculator. No cell phones.	15%	CLO1, CLO2, CLO3	D4, D7, D9
Final Exam	Final exam will cover whole course content. Part 1: MCQs via LMS, Part 2: numerical & derivations. Duration: 120~180 mins (May vary if taken online) Exam Specifications: Closed book, No calculator. No cell phones.	20%	CLO1, CLO2, CLO3	D4, D7, D9
Paper Presentation	This will be a group exercise and will be performed in a group of 2 students Duration: 2 weeks (towards the end of the course) Specifications: Paper summary, presentation with transcription and video	10%	CLO4, CLO5	D4, D7, D9, D10

Examination Detail	
Midterm Exam	Yes/No: No
Final Exam	Yes/No: Yes Combine Separate: Comprehensive Duration: 180 min Exam Specifications: Written
Makeup Policy	

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- Please refer to Student Handbook 2019-20, page 37, article 25, titled "Makeup Policy for Graded Instruments".
- *"In case N-X policy is implemented for an instrument having multiple sub instruments then petitions will not be accepted for that instrument".*

Code of Conduct

1. Students are required show up in class fully prepared for the lecture, ensure their videos and mic's are muted.
2. Quiz's will be announced ahead of time, students must ensure their devices are charged and they have a stable internet connection (including smartphones).
3. All assessments including quizzes, labs and tests will be timed. Make sure that you are able to start them on time.

Academic Honesty

The principles of truth and honesty are recognized as fundamental to a community of teachers and students. This means that all academic work will be done by the student to whom it is assigned without unauthorized aid of any kind. Plagiarism, cheating and other forms of academic dishonesty are prohibited. Any instances of academic dishonesty in this course (intentional or unintentional) will be dealt with swiftly and severely. Potential penalties include receiving a failing grade on the assignment in question or in the course overall. For further information, students should make themselves familiar with the relevant section of the LUMS student handbook.

Harassment Policy

SSE, LUMS and particularly this class, is a harassment free zone. There is absolutely zero tolerance for any behaviour that is intended or has the expected result of making anyone uncomfortable and negatively impacts the class environment, or any individual's ability to work to the best of their potential.

In case a differently-abled student requires accommodations for fully participating in the course, students are advised to contact the instructor so that they can be facilitated accordingly.

If you think that you may be a victim of harassment, or if you have observed any harassment occurring in the purview of this class, please reach out and speak to the instructor. If you are a victim, I strongly encourage you to reach out to the Office of Accessibility and Inclusion at oai@lums.edu.pk or the sexual harassment inquiry committee at harassment@lums.edu.pk for any queries, clarifications, or advice. You may choose to file an informal or a formal complaint to put an end of offending behavior. You can find more details regarding the LUMS sexual harassment policy at: https://mgshss.lums.edu.pk/lums-harassment-policy.

To file a complaint, please write to harassment@lums.edu.pk.

In addition to LUMS resources, SBASSE'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

A 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.

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COURSE OVERVIEW						
S#	**Module**	**L#**	**Topics Covered (tentative)**	**Recommended Readings**	**Related CLOs**	**ACM Computing Knowledge Landscape**
1	Introduction	1	Overview – Brain – Neuron - Hubel & Wiesel, 1959 What is Learning? What is Machine Learning Historical Context Shallow Feature Learning What is Classification? Shallow vs. Hierarchical vs. Deep Features (ML vs. DL) Course Logistics Success Stories	[Buduma] Ch 1	CLO1	CK3.2
2	Neural Networks Training Feed-Forward NN	1 1	What is Regression – Line fitting? The Neuron – Biologically Perceptron Linear Perceptron as Neuron Logistic Regression The Fast-Food Problem (Hinton / Buduma) Gradient Descent - Intuition The Delta Rules and Learning Rules Handout: MSE with Sigmoid, cross entropy+sig, MSE+Softmax, cross entropy+softmax Gradient Descent with Sigmoid Neurons More Derivative Examples (Ng) Computation Graph Derivatives with a Computation Graph Multi-layer Perceptron Gradient Descent The Back Propagation Algorithm Stochastic and Minibatch Gradient Descent	[Buduma] Ch 1 [Buduma] Ch 2	CLO1	CK3.2
3	Practical Aspects	3	Test Set, Validation Set, Overfitting Regularization Hyper parameter tuning Data Augmentation Vanishing/Exploding Gradients Weight/Initialization Methods???? Activation Functions Softmax Optimization Algos Gradient Descent with momentum Learning rate adaptation (AdaGrad, RMSProp, Adam)	[Buduma] Ch 2 [Buduma] Ch 4	CLO1	CK3.2

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S#	Module	L#	Topics Covered (tentative)	Recommended Readings	Related CLOs	ACM Computing Knowledge Landscape
4	ConvNet	3	Convolution-1D Convolution-2D Convolution-Filters (Edge detection) Forward and Backward Propagation using Convolution operation Transforming Multilayer Perceptron to Convolutional Neural Network Texture Classification Example + Filter Banks (Dr. Mohsen) A toy ConvNet: X's and O's Eg. (Brandon Rohrer)/ Full Arch Description on ConvNet Feature Maps Pooling, FC, Batch Normalization etc Closing the loop on MNIST with ConvNet Accelerating training with batch normalization Multi-Class Learning - Building a ConvNet for CIFAR-10 Transfer Learning	[Buduma] Ch 5	CLO1	CK3.2
5	ConvNet: Case Studies	2	Classical CNN: Case Studies AlexNet, VGG, GoogleNet, ResNet, ResNet, Inception, U-Net Relationship between ConvFilters and Receptive Field		CLO1	CK3.2
6	Autoencoders	3	Embedding and Representation Learning Learning Lower-Dimensional Representations Principal Component Analysis Motivating the Autoencoder Architecture Denoising to Force Robust Representations Sparsity in Autoencoders Stacked Autoencoders	[Buduma] Ch 6	CLO1	CK3.2
			Image Segmentation, Instance Segmentation Image Retrieval using Unsupervised/Semi-supervised Learning			
7	GANS	2	GANS Adversarial Learning Adversarial Attacks Adversarial AAE Discriminative AAE Cyclic GANS – CT+X-Ray Cross-View Generation – Remote Sensing		CLO1	CK3.2

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S#	Module	L#	Topics Covered	Recommended Readings	Related CLOs	ACM Computing Knowledge Landscape
8	Visualization	1	Visualizing filters and kernels Visualizing activations Stochastic Neighbour Embedding (SNE) Saliency vs. Occlusion Guided Backprop Gradient Ascent		CLO1	CK3.2
9	Object Detection	2	Classification + Regression Region Proposal Networks RCNN Faster RCNN YOLO: You Only Look Once SSD: Single Shot Detector		CLO1	CK3.2
10	Sequence Models	2	Intro to RNN & Back Prop through time Character RNN, Difference Units Recurrent Neural Networks The Challenges with Vanishing Gradients Long Short-Term Memory (LSTM) Units TensorFlow Primitives for RNN Models Implementing a Sentiment Analysis Model Solving seq2seq Tasks with Recurrent Neural Networks Augmenting Recurrent Networks with Attentio Dissecting a Neural Translation Network Deep Captioning Visual Question Generation	[Buduma] Ch 7	CLO1	CK3.2
11	Geometric Deep Learning	3	Applying Deep Learning on 3D Data Graph-based edge convolution Learnable local (non-linear) operator Dynamic Graph Neural Network Different Formulation of non-Euclidean CNNs Reimannian Geometry Calculus on Manifolds	geometricdeeplearning.com	CLO1	CK3.2
12	Deep Reinforcement Learning	2	Markov Decision Process Q-Learning Tool box The Bellman Equation Deep Q-Learning Policy Gradients	[Buduma] Ch 9	CLO1	CK3.2
13	Network Compression	2	Knowledge Distillation Offline/Online Pruning		CLO1	CK3.2
14	New Frontiers	1	Deep Fakes, Ethics in Deep Learning, Equivariance and Equivalent GPUS, TPU and Compute Sticks, Hardware Implementation		CLO6	CK3.2, CK6.4

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Sr #	Assignment Title	Assignment Statement	Topics Covered	Description of skills, tools, platform, etc. (e.g., Programming in C/C++, MS Visual Studio, Windows/Linux)	Proposed Duration	Related CLOs
1	Assignment 1 - Neural Network Class		Classification and Regression using Neural Networks		1.5 week(s)	CLO2, CLO3, CLO5
2	Assignment 2 - Hyperparameters		Hyperparameter tuning in Neural Networks		1.5 week(s)	CLO2, CLO3, CLO5
3	Assignment3 - CNNs		Convolution Neural Networks		2 week(s)	CLO2, CLO3, CLO5
4	Assignment 4 - AE and VAE		Autoencoders and Variational , Autoencoders		2 week(s)	CLO2, CLO3, CLO5
5	Assignment 5 - Conditional GANS		Generative Adversarial Networks		1.5 week(s)	CLO2, CLO3, CLO5
6	Assignment 6 - Network Compression		Network Compression		1.5 week(s)	CLO2, CLO3, CLO5
7	Paper Presentation		All topics covered in the course.		3 week(s)	CLO4, CLO5

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Appendix A
Bloom's Taxonomy

BLOOM's TAXONOMY*	
1 - Remember 2 - Understand 3 - Apply 4 - Analyze 5 - Evaluate 6 - Create	• Recall facts and basic concepts • Explain ideas or concepts • Use information in new situations • Draw connection among ideas • Justify a stand or decision • Produce new or original work

https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

Appendix B
ACM Dispositions Table - I

ACM Dispositions			
Element	**Elaboration**	**Element**	**Elaboration**
D1 Adaptable:	Flexible; agile, adjust in response to change	D7 Professional:	Professionalism, discretion, ethical, astute
D2 Collaborative:	Team player; willing to work with others	D8 Purpose-driven:	Goal driven, achieve goals, business acumen
D3 Inventive:	Exploratory; Look beyond simple solutions	D9 Responsible:	Use judgment, discretion, act appropriately
D4 Meticulous:	Attentive to detail; thoroughness, accurate	D10 Responsive:	Respectful; react quickly and positively
D5 Passionate:	Conviction, strong commitment, compelling	D11 Self-directed:	Self-motivated, determination, independent
D6 Proactive:	With initiative, self-starter, independent		

ACM Dispositions Table - II

Class Assessments and Proposed Dispositions												
Assessment Type	**D1 Adaptable**	**D2 Collaborative**	**D3 Inventive**	**D4 Meticulous**	**D5 Passionate**	**D6 Proactive**	**D7 Professional**	**D8 Purpose-driven**	**D9 Responsible**	**D10 Responsive**	**D11 Self-directed**	**Included**
Quiz				✓			✓		✓			Yes
Assignment-Individual			✓	✓			✓		✓			Yes
Assignment-Group		✓	✓	✓			✓		✓	✓		Yes
Project-Individual	✓		✓	✓	✓	✓	✓	✓	✓		✓	Yes
Project- Group	✓	✓	✓	✓	✓	✓	✓	✓	✓			Yes
Presentation-Individual				✓			✓		✓	✓	✓	Yes
Presentation-Group		✓		✓			✓		✓	✓		Yes
Labs-Individual			✓	✓			✓		✓			Yes
Labs- Group		✓	✓	✓			✓		✓	✓		Yes
Exams				✓			✓		✓			Yes
Included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	

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Appendix C
ACM Computing Knowledge Landscape Table

ACM Computing Knowledge Landscape (CK)			
1. Users and Organizations	CK1.1: Social Issues and Professional Practice CK1.2: Security Policy and Management CK1.3: IS Management and Leadership CK1.4: Enterprise Architecture CK1.5: Project Management CK1.6: User Experience Design	**4. Software Development**	CK4.1: Software Quality, Verification and Validation CK4.2: Software Process CK4.3: Software Modeling and Analysis CK4.4: Software Design CK4.5: Platform-Based Development
2. Systems Modeling	CK2.1: Security Issues and Principles CK2.2: Systems Analysis & Design CK2.3: Requirements Analysis and Specification CK2.4: Data and Information Management	**5. Software Fundamentals**	CK5.1: Graphics and Visualization CK5.2: Operating Systems CK5.3: Data Structures, Algorithms and Complexity CK5.4: Programming Languages CK5.5: Programming Fundamentals CK5.6: Computing Systems Fundamentals
3. Systems Architecture and Infrastructure	CK3.1: Virtual Systems and Services CK3.2: Intelligent Systems (AI) CK3.3: Internet of Things CK3.4: Parallel and Distributed Computing CK3.5: Computer Networks	**6. Hardware**	CK6.1: Architecture and Organization CK6.2: Digital Design CK6.3: Circuits and Electronics CK6.4: Signal Processing