DURHAM COLLEGE
SUCCESS MATTERS

Faculty of Sci, Eng, & IT

Advanced Neural Networks: Deep Learning for Sequential Analysis

2024-25 Academic Year

Program Title	Ministry Title	Major	Year	Semester
SEIT-Honours Bachelor of Artificial Intelligence	--	HBAI	4	7

Course Code:	COSC 41000	**Course Equiv. Code(s):**	N/A
Course Hours:	42	**Course GPA Weighting:**	3
Prerequisite:	Introduction to Artificial Neural Networks, Natural Language Processing		
Corequisite:	N/A		
Laptop Course:	**Yes** [ ] **No** [X]		
Delivery Mode(s):	**In class** [X] **Online** [ ] **Hybrid** [ ] **Flexible** [ ] **HyFlex** [ ]		
Remote proctoring required	**Yes** [ ] **No** [X]		
Authorized by (Dean or Director):	Tania Clerac	**Date:**	August 2024

Prepared by		
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Course Description:

The course introduces students to Methods in Deep Sequential Learning including Recurrent Neural Nets (RNNs), a class of modern artificial neural networks aimed at processing sequential data. The course goes on to introduce the problems of vanishing and exploding gradients as well as that of long-distance dependencies in sequential processing while offering their corresponding solutions. Students will focus on the theoretical and practical aspects of various types of sequential architectures (i.e., various types of RNNs and Transformer Architectures) and study their applications including those in natural language processing (including such tasks as language translation, automatic captioning, handwriting and speech recognition), log/sensor analysis, and time series anomaly detection.

Campus Closure Notice

In the event of a campus closure during which time classes cannot be conducted or attended in person, course delivery will be conducted remotely where possible. Should teaching and learning resume on campus, students may be organized into smaller groups for classroom delivery, in accordance with directions from public health authorities. In either situation, the learning plan sequence and/or evaluation methods may be adjusted to address topics requiring hands-on, practical learning activities.

Subject Eligibility for Prior Learning Assessment & Recognition (PLAR):

Prior Learning Assessment and Recognition (PLAR) is a process a student can use to gain college credit(s) for learning and skills acquired through previous life and work experiences. Candidates who successfully meet the course learning outcomes of a specific course may be granted credit based on the successful assessment of their prior learning. The type of assessment method (s) used will be determined by subject matter experts. Grades received for the PLAR challenge will be included in the calculation of a student's grade point average.

The PLAR application process is outlined in http://www.durhamcollege.ca/plar. Full-time and part-time students must adhere to all deadline dates. Please email: PLAR@durhamcollege.ca for details.

PLAR Eligibility

Yes [ ] **No** [X]

PLAR Assessment (if eligible):

- [ ] Assignment
- [ ] Exam
- [ ] Portfolio
- [ ] Other

Course Learning Outcomes

Course Learning Outcomes contribute to the achievement of Program Learning Outcomes for courses that lead to a credential (e.g. diploma). A complete list of Vocational/Program Learning Outcomes and Essential Employability Skill Outcomes are located in each Program Guide.

Ontario Qualfications Framework (OQF)	Course Learning Outcomes (CLOs)
Depth and Breadth of Knowledge	
Conceptual & Methodological Awareness	
Communication Skills	
Application of Knowledge	
Professional Capacity/Autonomy	
Awareness of Limits of Knowledge	

Evaluation Criteria:

The Course Learning Outcomes and Essential Employability Skills Outcomes are evaluated by the following evaluation criterion.

Evaluation Description	Course Learning Outcomes		Weighting
Assignment: Assignment 1: Implement an RNN	CLO1, CLO2, CLO3		15
Exam: Midterm Exam	CLO1, CLO2, CLO3, CLO4		25
Assignment: Assignment 2: Implement attention enabled architecture	CLO4, CLO5, CLO6		15
Exam: Final Exam	CLO5, CLO6, CLO7, CLO8		25
Project: Term Project: Implement an encoder decoder autoregressive algorithm	CLO7, CLO8		20
Total			**100%**

Notes:

Required Text(s) and Supplies:

1. McMahan, Brian, and Delip Rao. Natural Language Processing with PyTorch: Build Intelligent Language Applications Using Deep Learning. O'Reilly Media, 2019.
2. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. Deep Learning. MIT Press, 2015. Open source.
3. Vaswani, Ashish, et al. "Attention Is All You Need." Proceedings of the 31st International Conference on Neural Information Processing Systems (NIPS 2017), 2017. Open source.
4. Chintala, Soumith. "Official PyTorch Tutorial: 60min Blitz." PyTorch, https://pytorch.org/tutorials/beginner/deep_learning_60min_blitz.html. Accessed May 28, 2024.
5. Sennrich, Rico, Barry Haddow, and Alexandra Birch. "Neural Machine Translation of Rare Words with Subword Units." 2016. Open source.
6. Devlin, Jacob, et al. "BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding." 2018. Open source.

Recommended Resources (purchase is optional):

1. Jurafsky, Daniel, and James H. Martin. Speech and Language Processing. 3rd ed., Pearson, 2019.
2. Deng, Li, and Yang Liu. Deep Learning in Natural Language Processing. Springer, 2018.
3. Kostadinov, Simeon. Recurrent Neural Networks with Python Quick Start Guide: Sequential Learning and Language Modeling with TensorFlow. Packt Publishing, 2018.

Policies and Expectations for the Learning Environment:

General Policies and Expectations:

General College policies related to	General policies related to
+ Acceptable Use of Information Technology + Academic Policies + Academic Integrity + Standards for Student Conduct for all Learning Environments can be found at https://durhamcollege.ca/wp-content/uploads/Standards-of-Student-Conduct-for-all-Learning-Environments.pdf + Information about academic policies and procedures can be found on-line at https://durhamcollege.ca/about/governance/policies	+ attendance + absence related to tests or assignment due dates + excused absences + writing tests and assignments + classroom management can be found in the Program Guide (full time programs only) in MyDC https://durhamcollege.ca/mydc/

All students at Durham College have the responsibility to familiarize themselves with and abide by the college's Academic Integrity Policy. Students are expected to complete and submit their own work in an honest manner, in accordance with the policy. Durham College has zero tolerance for breaches of academic integrity. All suspected breaches of academic integrity will be investigated and documented following procedures outlined in the policy, and should a breach be confirmed, appropriate penalties will be levied. Breaches of academic integrity refer to a variety of practices including, but not limited to:

• copying another person's work;
• using unauthorized materials or resources during an evaluation;
• obtaining unauthorized copies of evaluations in advance;
• collaborating without permission;
• colluding or providing unauthorized assistance;
• falsifying academic documents or records;
• misrepresenting academic credentials;
• buying, selling, stealing, soliciting, exchanging or transacting materials or information for the purpose of academic gain;
• bribing or attempting to bribe personnel;
• impersonation;
• submitting the same work in more than one course without authorization;
• improper use of computer technology and the internet;
• depriving others of academic resources;
• misrepresenting reasons for special consideration of academic work;
• plagiarizing or failing to acknowledge ideas, data, graphics or other content without proper and full acknowledgement;
• any unauthorized use of generative or other artificial intelligence.

If you have questions or concerns about what constitutes appropriate academic conduct or research and citation methods, and what your responsibilities are towards academic integrity, please visit the Academic Integrity website on MyDC, reach out to Student Academic Learning Services (SALS), or speak with your professor or Student Advisor.

Course Specific Policies and Expectations:

General Course Outline Notes:

1. Students should use the course outline as a learning tool to guide their achievement of the learning outcomes for this course. Specific questions should be directed to their individual professor.
2. The college considers the electronic communication methods (i.e. DC Mail or DC Connect) as the primary channel of communication. Students should check the sources regularly for current course information.
3. Professors are responsible for following this outline and facilitating the learning as detailed in this outline.
4. Course outlines should be retained for future needs (i.e. university credits, transfer of credits etc.)
5. A full description of the Academic Appeals Process can be found at https://durhamcollege.ca/about/governance/policies/academic-policies .
6. Faculty are committed to ensuring accessible learning for all students. Students who would like assistance with academic access and accommodations in accordance with the Ontario Human Rights Code should register with the Access and Support Centre (ASC). ASC is located in room SW116, Oshawa Campus and in room 180 at the Whitby Campus. Contact ASC at 905-721-3123 for more information.
7. Durham College is committed to the fundamental values of preserving academic integrity. Durham College and faculty members reserve the right to use electronic means to detect and help prevent plagiarism. Students agree that by taking this course all assignments could be subject to submission either by themselves or by the faculty member for a review of textual similarity to Turnitin.com. Further information about Turnitin can be found on the Turnitin.com Web site.

Learning Plan

The Learning Plan is a planning guideline. Actual delivery of content may vary with circumstances.

Students will be notified in writing of changes that involve the addition or deletion of learning outcomes or evaluations, prior to changes being implemented, as specified in the Course Outline Policy and Procedure at Durham College.

Week/ Module	**Hours:** 3 **Delivery:** In Class
1	**Course Learning Outcomes** CLO2
	Intended Learning Objectives/Topics Course Syllabus & Outline Course Materials Topics per session Evaluation What is Sequential Analysis -Historical Analysis -Predictive Analysis Introduction to Pytorch -Installing PyTorch -Creating Tensors -Tensor Types and Size -Tensor Operations -Numpy Bridge -Indexing, Slicing, and Joining -Tensors and Computational Graphs -CUDA Tensors -Apply basic data structure and operations in Pytorch
	Intended Learning Activities Lecture, Review, Programming
	Resources and References N/A
	Evaluation

Week/ Module	**Hours:** 3 **Delivery:** In Class
2	**Course Learning Outcomes** CLO3, CLO4, CLO7, CLO8
	Intended Learning Objectives/Topics
	Topics: Encoding Discrete Values & Target -One-hot -TF-IDF -Encoding Target Pytorch Pattern -Autograd -Gradients -Loss Function -nn.Module Inheritance -Neural Net Class -Backprop -Weight Updating -Optimizer -Training Iteration -Testing a Network -Training on a GPU Intended Learning Objectives: -Create continuous representation out of discrete values for inputs to the network for a deep learning problem -Create the correct encoding as target values for a deep learning problem -Apply general pytorch model development pattern
	Intended Learning Activities Lecture, Programming
	Resources and References McMahan & Rao Chapter 1 Chintala: entire 60 min Blitz tutorial
	Evaluation

Week/ Module	**Hours:** 3 **Delivery:** In Class
3	**Course Learning Outcomes** CLO3, CLO4, CLO6, CLO7, CLO8
	Intended Learning Objectives/Topics
	Topics: Activation Functions in Pytorch Prominent Loss Functions -Mean Squared Error Loss -Categorical Cross-Entropy Loss --Binary Cross-Entropy Loss Gradient-Based Supervised Learning in Pytorch Model Performance Evaluation Hyperparameter Optimization Regularization -Exercise: Classifying Sentiment of Restaurant Reviews Word Embeddings -Learning word embeddings -Transfer learning using word embeddings Intended Learning Objectives: Apply various types of activation functions in Pytorch -Apply prominent loss functions in Pytorch -Apply model validation steps using Pytorch -Create a deep sentiment analyzer -Apply word embeddings to improve a downstream task
	Intended Learning Activities Lecture, programming, in-class exercise
	Resources and References McMahan & Rao Chapters 3 and 5
	Evaluation

Week/ Module	**Hours:** 3 **Delivery:** In Class
4	**Course Learning Outcomes** CLO1, CLO2, CLO3
	Intended Learning Objectives/Topics
	Topics: Introduction to RNNs -Unfolding Computational Graphs -Backpropagation Through Time (BPTT) -Elman network -Jordan network Exercise: implement a character RNN -Dataset Class -Vectorization Data Structures -Teacher Forcing The closed loop issue -Gradients in RNNs Intended Learning Objectives: -Apply an RNN to a sequential processing task Explain the significance of BPTT -Apply the Elmanian Architecture to solve a sequential processing task -Apply BPTT to train an RNN
	Intended Learning Activities Lecture, Programming
	Resources and References McMahan & Rao Chapter 6 Goodfellow and Bengio Chapters 10.0-10.3
	Evaluation

Week/ Module	Hours: 3 Delivery: In Class
5	**Course Learning Outcomes** CLO1, CLO4, CLO5, CLO7
	Intended Learning Objectives/Topics Topics: Intermediate RNNs -The issue with vanilla RNNs -Echo State Networks -Leaky Units and Multiple Time Scales -Gates to address the vanilla RNN problem -LSTMs -GRUs -Generative RNNs Intended Learning Objectives: -Explain the main issues with vanilla rnns in sequential processing -Apply different methods to tackle the issue of long distance dependencies in RNNs
	Intended Learning Activities Lecture, Programming
	Resources and References McMahan & Rao Chapter 7 Goodfellow and Bengio Chapter 10.7-10.10
	Evaluation — **Weighting** Assignment: Assignment 1: Implement an RNN — 15
Week/ Module	**Hours:** 3 **Delivery:** In Class
6	**Course Learning Outcomes** CLO1, CLO2, CLO3, CLO4, CLO5, CLO6, CLO7, CLO8
	Intended Learning Objectives/Topics Topics: Midterm Test Term Project: Implement an encoder decoder autoregressive algorithm
	Intended Learning Activities Lecture, Programming
	Resources and References Midterm Test Due: from materials taught in weeks 1, 2, 3, 4 and 5 (25%)
	Evaluation — **Weighting** Exam: Midterm Exam — 25

Week/ Module	**Hours:** 3 **Delivery:** In Class
7	**Course Learning Outcomes** CLO1, CLO8
	Intended Learning Objectives/Topics
	Topics: Advanced RNNs -Bidirectional RNNs -Sequence-to-Sequence Models -Encoder-Decoder Models -Conditioned Generation -Bidirectional RNNs Exercise: Restaurant Sentiment Classification using Bidirectional RNNs Intended Learning Objectives: -Apply Bidirectional RNNs to a sequential processing task -Explain sequence to sequence models in sequential processing -Explain encoder-decoder architecture in sequential processing
	Intended Learning Activities Lecture, Programming
	Resources and References McMahan & Rao Chapter 8 Goodfellow and Bengio Chapter 10.3-10.4
	Evaluation

Week/ Module	Hours: 3 Delivery: In Class
8	**Course Learning Outcomes** CLO5, CLO8
	Intended Learning Objectives/Topics Topics: -Attention Mechanism -Evaluating Sequence Generation Models -Neural Machine Translation -Dataset for MT -Vectorization for NMT -Encoding and Decoding for NMT --Greedy Search --Beem Search --Top k Random Sampling -Training and Results Intended Learning Objectives: -Apply the attention mechanism for a sequential processing task -Evaluate a sequence generation model to determine its performance -Apply a neural machine translation algorithm -Evaluate the performance of an NMT algorithm
	Intended Learning Activities Lecture, Programming
	Resources and References McMahan & Rao Chapter 8
	Evaluation

Week/ Module	Hours: 3 Delivery: In Class
9	**Course Learning Outcomes** CLO4, CLO5
	Intended Learning Objectives/Topics Topics: Optimization pertinent to Long-term dependencies -Clipping Gradients -Regularizing to incentivize the flow of information Explicit memory and memory networks Intended Learning Objectives: -Apply a memory network to a sequential processing task
	Intended Learning Activities Lecture, Programming
	Resources and References Goodfellow and Bengio Chapter 10.11-10.12
	Evaluation **Weighting** Assignment: Assignment 2: Implement attention enabled architecture 15

Week/ Module	**Hours:** 3 **Delivery:** In Class
10	**Course Learning Outcomes** CLO5, CLO6
	Intended Learning Objectives/Topics
	Topics: Transformer Architecture -Absence of Recurrence -Positional Encoding -Self Attention Layer: --Types of sub-layers --Parallelizing Attention -Query -Key -Value --Layer Norm --Scaled dot product in self attention --Multi-Head Attention Intended Learning Objectives: -Explain the merits of the transformer architecture -Implement the parallelized attention using query, key, and value triplets
	Intended Learning Activities Lecture, Programming
	Resources and References Vaswani et al 2017
	Evaluation

Week/ Module	**Hours:** 3 **Delivery:** In Class
11	**Course Learning Outcomes** CLO8
	Intended Learning Objectives/Topics
	Topics: Transformer Architecture - continued -Padding Masks (encoder & decoder) -Decoder Masking Types of Vocabulary Encoding -Word Encoding --Pros & Cons -Char Encoding --Pros and Cons -Byte Pair Encoding (BPE) --Advantages Intended Learning Objectives: -Apply encoder and decoder masks in a transformer architecture -Apply Byte Pair Encoding
	Intended Learning Activities Lecture, Programming
	Resources and References Vaswani et al 2017 Sennrich et al 2015
	Evaluation

Week/ Module	**Hours:** 3 **Delivery:** In Class
12	**Course Learning Outcomes** CLO5, CLO7
	Intended Learning Objectives/Topics
	Topics: BERT -Architecture -Input/Output Representation -Pretraining --Masked LM --Next Sentence Prediction -Fine-tuning -Benchmarks --GLUE --SQuAD --SWAG Intended Learning Objectives: -Create attention based pretrained embeddings using BERT -Fine-tune BERT to address multiple NLP tasks
	Intended Learning Activities Lecture, Programming
	Resources and References Devlin et al 2018
	Evaluation **Weighting** Project: Term Project: Implement an encoder decoder autoregressive algorithm 20
Week/ Module	**Hours:** 3 **Delivery:** In Class
13	**Course Learning Outcomes** CLO1, CLO2, CLO3, CLO4, CLO5, CLO6, CLO7, CLO8
	Intended Learning Objectives/Topics
	Topics: Review Session -Any questions about the material taught throughout the class is answered -Any implementation questions with regard to the term project are addressed Intended Learning Objectives: -The students can use this session to work on their term project and ask any questions they may have during the class
	Intended Learning Activities Review, In-class exercise
	Resources and References N/A
	Evaluation

Week/ Module	**Hours:** 3 **Delivery:** In Class	
14	**Course Learning Outcomes** CLO1, CLO2, CLO3, CLO4, CLO5, CLO6, CLO7, CLO8	
	Intended Learning Objectives/Topics	
	Topics: Final Exam Term Project Due	
	Intended Learning Activities Lecture, Programming	
	Resources and References N/A	
	Evaluation Exam: Final Exam	**Weighting** 25