Neural and Cognitive Computing
CISC-874/3.0 (36L, 84P)
Token Type: T, A

Course Description
Theoretical foundation and practical applications of Artificial Neural Networks (ANN) and Cognitive Computing (CC) models. Paradigms of neural computing algorithms using attention and context embedding models, applications in cognitive modeling, artificial intelligence, and machine learning with multi-stream data processing techniques.

Prerequisites: Knowledge of relational algebra

Time Commitment
Students are expected to spend 120 hours per term in lecture and practice.

Learning Outcomes:
1. Explain foundational concepts such as operation of biological neurons and learning in artificial intelligence (AI) influenced by cognitive modeling theories such as perceptual bias, memory, attention, context embedding, and belief.
2. Apply theoretical knowledge in developing computational models for cognitive modeling, language understanding, decision support, behavior analysis, question answering, image processing, and action recognition.
3. Explore and critically analyze recent research on cognitive modeling to explain human cognition and memory using data from social networks, application of deep neural models in computer vision, language understanding in intelligent chatbots, and multi-sensor stream data processing for predictive analytics and decision support.
4. Explain the power and limitations of neural cognitive systems.

Assessment:
- Assignments: 25%
- Quizzes: 25%
- Literature Review and Talk
- Project: 30% (code, talk and demo, report)

Required Materials
1. **Elements of Artificial Neural Networks**
   By Mehrotra, Mohan, and Ranka
   2nd Edition (ebook available to order using the following link or from Amazon.ca)
2. Introduction to Cognitive Science

Implementation Environment
- Matlab, python, Keras, Tensorflow

Assessment Structure and Description

Assessment (formative and summative)	Formative or Summative	Weight	Alignment with Learning Outcomes
Quizzes	Summative	25%	1, 2
Project	Summative with formative elements	30%	1, 2, 3, 4
Individual Assignments	Summative with formative elements	45%	2, 4

Weekly Syllabus

Week 1 : Introduction

Topics

Introduction to biological neurons and the evolution of Artificial Neural Network (ANN) models. Applications to human cognition. General architecture and concepts behind ANN and its application in machine learning. Learning algorithms in TLU and Perceptron using simple feedback learning.

Readings

Textbook Chapter 1 and additional online material.

Activities

- Project topic selection: text cognition, visual cognition, multimodal cognition and prediction
- Find project relevant papers.

Week 2 : Supervised Learning and Concepts from Cognitive Computing

Topics

Multi-layer deep learning models, Adaline, backpropagation, supervised learning, concepts from cognitive computing such as attention, multi-stream processing, contextual understanding, belief, memory, and perceptual bias. How do we form belief, how do we apply logic, logical reasoning, abductive reasoning as correlation learning, goal optimization and reinforcement learning.

Readings

Textbook Chapter 2 and/or additional online material.

Activities

- Assignment on coding a multilayer ANN without using any library.

Week 3 : Multilayer Complex Neural Computing Models

Topics

Using neural models for sequence and spatial pattern learning, adaptive models, optimization techniques. Research talk on Cognitive Computing.

Readings

Textbook Chapter 3 and/or additional online material.

Activities

- Research paper summarization for literature review reporting and presentation.

Week 4 : Multilayer ANNs, Unsupervised Learning and Introduction to Deep Learning

Topics

Simple competitive learning for distance computation using neural computing models for streaming data, Hamming network, maxnet, Kohonen network, neural K-means, Learning Vector Quantizers (LVQ), Adaptive Resonance Theory (ART), Self -Organizing Map (SOM), neural model for Principal Component Analysis (PCA).

Readings

Textbook Chapter 3 and/or additional online material.

Activities

- Submit assignment 1 (15%).

Week 5 : Paper presentation on Project Topic aligned with CC concepts

Topics

Select and present a paper on the topic of the project.

Readings

Online material.

Activities

- In-class paper presentation. Submit PPTX.

Week 6 : Associative Memory Models and Correlation Learning in ANNs and Autoencoders

Topics

Hebbian learning, deep belief network, autoencoders, self-supervised learning, attention models.

Readings

Textbook Chapter 5 and/or additional online material.

Activities

- Individual Assignment #2 posted
- Submit a literature review on 5 papers.

Week 7 : Research Talk on Applications of Cognitive Computing

Topics

Autoencoder, Text Embedding, Medical Data Analytics

Readings

Online material.

Activities

- Submit assignment 2 (10%).

Week 8 : Student Presentation of Deep Neural Models for Project

Topics

Specific implementations of object detection, segmentation, text encoding, generative models

Readings

Online material.

Activities

- Submit presentation PPTX and project implementation plan.

Week 9 : Invited Research Talks

Topics

Radial Basis Function, Boltzmann machine, hetero association models, Bidirectional Associative Memory (BAM).

Readings

Additional online material.

Activities

- Quiz #2

Week 10 : Quiz and Other Recent Neural Models

Topics

Bidirectional Encoder Representations from Transformers (BERT) Models and Multistream Encoding

Readings

Student Papers and additional online material.

Activities

- Group project topic discussions

Week 11 : Project Presentations and Discussions

Topics

Cutting edge research presentations on ANN.

Readings

Online material.

Activities

- Group project presentations

Week 12 : Project Presentations and Discussions

Topics

Presentations of group projects.

Readings

Papers relevant to the group work.

Activities

- Group project presentations
- Final report submission and code demo – problem description and motivation, existing research – strengths and weaknesses based on literature review, model implemented, data processing, training and validation, results and discussion.