MSiA 432: Deep Learning

Northwestern University

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Course Overview

Deep learning is a subset of machine learning and a branch of Artificial Intelligence (AI). It involves the training, deployment, and application of large complex neural network architectures to solve cutting-edge problems. Deep Learning has become the primary approach for solving cognitive problems such as Computer Vision, Natural Language Processing (NLP), Protein Folding, etc, and has had a massive impact on various industries such as healthcare, retail, automotive, industrial automation, and agriculture.
This course will enable students to build Deep Learning models and apply them to computer vision tasks such as object recognition, detection, and segmentation. Students will gain an in-depth understanding of the Deep Learning model development process, tools, and frameworks. Although the focus of the course will primarily be computer vision, students will work on both image and non-image datasets during class exercises and assignments. The course will be taught in Python using Deep Learning frameworks such as Tensorflow, Keras, and PyTorch.

Learning Objectives

After completing this course, students should be able to:

1. Understand various Deep Learning architectures for cognitive tasks.
2. Learn about best practices in training and optimizing deep neural networks.
3. Apply state-of-the-art DL models such as ResNet, YOLO, LSTMs, Transformers, etc.
4. Perform image processing and transformations using Python libraries.
5. Understand ML/AI capabilities on the cloud and learn to deploy and scale models operations.
6. Learn about the leading-edge research in DL through paper reviews and discussion.
7. Produce living documents with code, graphs, and text using Jupyter Notebooks.

Prerequisites

- Know your computer (Setting environment variables, Using the Mac/PC terminal, traversing applications/folders, updating security preferences)
- Programming for Analytics - Python
- Machine Learning
- Familiarity with data engineering and cloud computing

Course Materials

Class topics are sourced from multiple sources including the following recommended books. While reading assignments will be supplemented, the books jointly cover most of the topics covered in the class. Note: The hands-on exercises in class as well as assignments have been custom designed for this course and are based on public data sources.

Recommended Books:

- Deep Learning (Adaptive Computation and Machine Learning series) - Ian Goodfellow
- Deep Learning with Python - Francois Chollet
- Python Machine Learning - Sebastian Raschka
- Hands on Machine Learning - Aurélien Géron

Software

This course will require working in

- Python Anaconda, Jupyter Notebooks
- Python libraries – Pandas, Sklearn, Matplotlib, Seaborn, etc.
- Docker

Note: These software applications work best on PC's/Macs. Ensure the computer you are using provides you with the authority to perform these installs. Some work-related computers may not permit such installations without admin rights.

INFRASTRUCTURE

DeepDish @ Northwestern University

Google Colab

Sagemaker Studio Lab

Course Work

Assignments

The course will include 3 assignments involving data mining problems and coding which account for 60% of your grades.

- All the code and solutions in the individual assignments must be your own.
- If the same code is identified across assignments, students will be penalized.
- You may use code from the interactive repository, lecture examples, and other reference. material as inspiration but you may not copy and paste any functions into your code.
- Collaboration is only permitted for team projects.

Late Policy

- 20% for the first day it is late.
- 10% for every additional day it is late.

Team Project

The goal of the team project is to apply data mining techniques and best practices to real world problems. Students will team up as groups of 3 or 4 to collaborate on a public dataset or a Kaggle competition. Students will present their approach, algorithms, and findings as a team during the final presentation in Week 10. More details about the project will be provided in the course material.
The final project accounts for **30%** of your overall grade, and the project report will include the following sections:

- Abstract
- Paper Review and Model Approach
- Data Analysis and Model Development
- Findings and Conclusion

Class Participation

Class participation includes but is not limited to the following activities:

- Class attendance and quizzes
- Engaging in class and online discussions

Evaluation

You will pass this course provided you complete the following:

- Assignments (3) - 60 %
- Final Project - 30%
- Class Participation – 10%

Course Schedule

Week 1: Introduction to Deep Learning

- AI & Deep Learning Overview
- Machine Learning vs Deep Learning
- Applied DL in industry and research
- DL Frameworks and tools
- Lab: Software Installation

Week 2: Artificial Neural Networks (ANN)

- Optimization - Gradient Descent and Variations
- Introduction to ANNs
- Activation Functions
- Backpropagation
- Lab: ANN Implementation, Tensorflow.js
- Paper Selection, Teams

Week 3: Deep Neural Networks (DNN)

- Deep Neural Networks
- Deep Learning challenges and solutions
- Regularization and Hyperparameter Tuning
- Introduction to Tensorflow and Keras
- Lab: TensorFlow and PyTorch Basics, Keras DL
- Assignment 1 due

Week 4: Image Processing

- Introduction to Image Processing
- Image Transformations - Thresholding, Rotations
- Image and Signal filtering
- Lab: Image processing techniques in Python
- Project review checkpoint 1

Week 5: Computer Vision - Object recognition

- Convolutional Neural Networks (CNN)
- Object Recognition tasks
- Advanced CNN Architectures
- Lab: Image classification using CNN
- Assignment 2 due

Week 6: Computer Vision - Transfer Learning

- Transfer Learning
- Image Labeling techniques
- Computer vision – Object Detection tasks, Models: R-CNN, YOLO
- Self-Supervised Learning
- Project review checkpoint 3
- Lab: Transfer Learning, Object Detection, Segmentation

Week 7: Sequence Models

- Recurrent Neural Networks (RNN)
- Long Term Short Memory (LSTM)
- Gated Recurrent Units (GRUs)
- Lab: LSTM applied to time series, and NLP
- Assignment 3 due

Week 8: Transformer Models

- Attention Models
- Transformers
- Vision Transformers
- Neural Style Transfer
- Lab: Vit, Style Transfer, Object Counting
- Project review checkpoint 2

Week 9: Generative Models

- Introduction to Generative Models
- Autoencoders and Variational Autoencoders (VAE)
- Generative Adversarial Models (GAN)
- Lab: Image generation implementations

Week 10 (Final Project)

- Team presentations (20 mins per team)
- Q & A discussion
- Final Project due