CSC578: Neural Networks and Deep Learning

Tianxiang (Adam) Gao

January 9, 2025

Course Information

- **Sections**: 801 (Loop; in-class), 841 (Online; Flex)
- **Lectures**:
  - Meeting Time: Thursdays 5:45 PM – 9:00 PM
  - Location: CDM Center 224 or Live Lectures
- **Instructor**: Tianxiang (Adam) Gao
  - Research: Deep learning theory, generative AI, graph representation learning
  - Office: CDM 712
  - Zoom: https://depaul.zoom.us/my/gaotx
  - Email: t.gao@depaul.edu
  - Office Hours: Mondays 9:00 AM - 11:00 AM by Zoom or by Appointments
- **Course Website & Materials**:
  - D2L: https://d2l.depaul.edu/
  - Github: https://gaotx-cs.github.io/teaching/csc578/

Prerequisites

- **Prerequisites Courses**:
  - CSC 412: Tools and Techniques for Computational Analysis
  - CSC 480 (or DSC 478): Artificial Intelligence I
- **Required Knowledge**:
  - Calculus: derivatives of multivariate functions, chain rules
  - Linear Algebra: vectors, matrices, matrix-vector computations,
  - Probability: mean, variance, Gaussian distribution, conditional probability, Bayes' rule
  - Programming (Python): list, loops, functions, Numpy, Matplotlib, Jupyter
- **Textbooks**:
  - Neural Networks and Deep Learning, by Michael Nielsen.
  - Deep Learning Book, by Goodfellow, Bengio, and Courville.
  - The course is **self-contained** and complemented with research papers.
- **Additional Materials**: D2L or Github
  - Lecture slices
  - Research papers and blogs
  - Additional readings and reviews
  - This will be useful for course projects.

Course Overview

The course provides an essential introduction to neural networks and deep learning

- **Foundation of Deep Learning**: Multilayer perceptions, backpropagation, SGD
- **Advanced Optimization**: Momentum, RMSprop, Adam.
- **Generalization & Regularization**: overparameterization, double descent, weight decay.
- **Neural Network Architectures**: CNNs, RNNs, transformers (e.g., GPT and BERT)
- **Applications**: CV, NLP, and Bio such as Face recognition, language models, and drug side effects.

Course Outline

Week	Date	Topic
Week 1	Thu, 01/09	Introduction to Neural Networks
Week 2	Thu, 01/16	Training Neural Networks
Week 3	Thu, 01/23	Advanced Optimization Methods
Week 4	Thu, 01/30	Generalization and Regularization
Week 5	Thu, 02/06	Convolutional Neural Networks (CNNs)
Week 6	Thu, 02/13	Learning in CNNs
Week 7	Thu, 02/20	Recurrent Neural Networks (RNNs)
Week 8	Thu, 02/27	Sequence-to-Sequence Models
Week 9	Thu, 03/06	Large Language Models (LLM)
Week 10	Thu, 03/13	Graph Neural Networks (GNNs)
Week 11	Thu, 03/20	Final Project Due (No meeting)

Course Objective

By the end of this course, you should be able to:

- Understand the fundamentals of deep neural networks
- Explore advanced topics such as convolutional neural networks (CNNs), recurrent neural networks (RNNs), and transformer architectures.
- Gain practical experience through assignments and projects implementing deep learning models in Python using popular frameworks (e.g., PyTorch).
- Learn how to apply deep learning techniques to real-world problems such as computer vision, natural language processing, and biomedical data science.

Coursework

- **Quiz (25%)**:
  - Quizzes will generally be released on **Thursdays** and will be due on the next lecture.
  - We will count your best 5 out of the 10 quizzes.
  - Each quiz will consist of around 10 multiple-choice questions (∼0.5-1h).
- **Assignments (35%)**
  - These assignments are usually released on **Thursdays** and are due on the next lecture.
  - Students should fill in the correct code for implementation rather than starting from scratch (∼1-2h).
  - Download the Jupyter Notebook from D2L and fill in only the designated code sections.
  - Submit the notebook in its original format (.ipynb); do not change other parts of the file.
  - Any violation, such as altering the notebook or submitting a different format, will result in a **zero**.
  - We will count your best 5 out of the 10 assignments.
- **Midterm (20%)**
  - Take-home, open-book, individual work, no internet, honor code, timed
  - Released at 5 PM on Tuesday, February 4, available until 5 PM on Thursday, February 6.
  - Once you open it, you will have 120 minutes to complete the exam.
  - Content will be like quizzes and homework: **multiple-choice** questions and **coding** parts.
  - More details to announce.

Coursework

- **Final Project** (20%): Includes Proposal (0-8%) and Final Report (12-20%).
  - **Individual Project:** Team size is **one**. Larger teams require instructor approval.
  - **Research-Oriented:**
    - Motivation for the project
    - Limitations of existing methods
    - New methods/models/analyses proposed
    - New applications identified
    - Experimental support and discussion
  - **Example Projects:** Stanford CS231n
  - **LaTeX (Overleaf Tutorial)**: A Latex template will be provided; other templates are **not** allowed.
- **Extra Credit (5%):**
  - Course feedback, bonus assignments or problems, participation in class discussions, etc.
  - Used if you are on the boundary between grades.

Project Proposal Overview

Key Points:

- **Main paper:** 2-page limit (excluding references and appendix).
- **Sections:**
  - **Introduction:** Clearly define the machine learning problem, its significance, and key challenges.
  - **Related Work:** Summarize key papers and highlight your proposed improvements.
  - **Methodology:** Describe your approach, including architecture and planned innovations.
  - **Experimental Evaluation:** Specify datasets, evaluation metrics, and analysis methods.
  - **Work Plan:** Provide a timeline with major milestones and deadlines.
- **Appendix:** *Unlimited* supplementary material, such as code or detailed data explanations.

Submission: Submit as a **single PDF file**.

Final Project Report Guidelines

Submission Details:

- Total Points: **20 (or 12)**.
- Submit **two files: Final Project Report** (`.pdf`) and **Jupyter Notebook** (`.ipynb`).

Report Requirements:

- **Length:** 5-page limit for the main paper (unlimited references and appendix).
- **Sections:** Abstract, Introduction, Related Work, Background, Methodology, Numerical Experiments, Conclusion.

Notebook Requirements:

- Include well-annotated code, detailed explanations, and test cases.
- **Sections:** Libraries, Model Design, Training, Evaluation Results.

Submission Guidelines:

- Both `.pdf` and `.ipynb` files are required; missing either result in a zero score.
- **No late submissions will be accepted.**

Assessments Schedule and Due Dates

Week	Assessments	Release on (00:01 AM)	Due on (11:59 PM)
Week 1	Quiz 1, HW1	Thu, 01/09	Thu, 01/16
Week 2	Quiz 2, HW2	Thu, 01/16	Thu, 01/23
Week 3	Quiz 3, HW3	Thu, 01/23	Thu, 01/30
Week 4	Quiz 4, HW4	Thu, 01/30	Thu, 02/06
Week 5	Quiz 5, HW5	Thu, 02/06	Thu, 02/13
Week 5	**Midterm Exam**	**Tue, 02/04 5 PM**	**Thu, 02/06 5 PM**
Week 6	**Project Proposal**	Thu, 01/09	Thu, 02/20
Week 6	Quiz 6, HW6	Thu, 02/13	Thu, 02/20
Week 7	Quiz 7, HW7	Thu, 02/20	Thu, 02/27
Week 8	Quiz 8, HW8	Thu, 02/27	Thu, 03/06
Week 9	Quiz 9, HW9	Thu, 03/06	Thu, 03/13
Week 10	Quiz 10, HW10	Thu, 03/13	Thu, 03/20
Week 11	Final Project	Thu, 01/09	Thu, 03/20

Late Submissions

- Generally, submissions are due at 11:59 pm of the respective due date.
- Late submissions for *quizzes* are not allowed.
- *Assignments* and *Proposal* allow late submissions, up to 3 days late, where a penalty of 10 percent will be imposed for each day.
- No late submissions are accepted for the *Final Project*.

Grading Scale

Grade	Range
A	93-100
A-	90-92
B+	87-89
B	83-86
B-	80-82
C+	77-79
C	73-76
C-	70-72
D+	67-69
D	63-66
D-	60-62
F	0-59

University and Course Policies

- **Academic Integrity**
  - Cheating, plagiarism, and other forms of academic dishonesty are strictly prohibited.
  - Violations may result in failing the assignment, the course, or referral to the academic conduct committee.
  - Please ensure that all work submitted is your own and properly cited.
  - For detailed guidelines, refer to the university's academic integrity policy.
- **Other Policies**
  - We adhere to all university and course policies, including those on attendance, accommodations, and student conduct.
  - Detailed information on these policies can be found on the university policies website, or on the Teaching Commons page.

Note: For a comprehensive list of policies, please refer to the course **syllabus**.

Introduce Yourself (Extra Credit 1%)

Please introduce yourself by sharing your responses to the following prompts and post your introduction in the online discussion so we can all get to know each other better:

- **Name (and Preferred Pronouns)**
- **Major and Year**
- **Background (and Previous Experience)**
- **Research Interests**
- **Why You're Taking the Course**
- **Expectations for the Course**
- **Fun Fact or Hobby**

Discussion Questions

Questions to Discuss:

- What is Artificial Intelligence (AI)?
- What is Machine Learning (ML)?
- What is Deep Learning (DL)?
- What are the pros and cons of DL compared to conventional machine learning?

Instructions: Discuss these questions in small groups of 2-3 members.