CS 4782: Introduction to Deep Learning
Course Staff

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ML/AI Courses at Cornell

CS 4780: Introduction to Machine Learning
CS 4756: Robot Learning
CS 4670: Introduction to Computer Vision
CS 4744: Computational Linguistics I
CS 4789: Introduction to Reinforcement Learning
CS 4775: Computational Genetics and Genomics
CS 4740: Natural Language Processing
Logistics

- All lectures will be held in person at Stocking Hall 202
- Lectures will be on Tuesdays and Thursdays from 2:55 to 4:10pm
- Aiming to have a small class
  - If you are on the waitlist, come talk to us after class
- Please participate!!
Logistics

- Course website: [https://www.cs.cornell.edu/courses/cs4782/2024sp/](https://www.cs.cornell.edu/courses/cs4782/2024sp/)
  - Tentative schedule, homework policies, grading policies, etc. are on the course page
- Office hours are on the course website!
- We also have a Canvas page
  - Links to the Ed Discussion
- No laptops/mobiles-smart devices and other devices in class please
- Notes will be printed
Grading

- **Homework (30%)**
  - There will be written assignments and coding projects
    - Google Cloud Credits for compute!
  - We recommend doing them in pairs!
  - 2-slip days for every assignment

- **Mid-term exam (30%)**
  - Will be similar to the homework assignments

- **Project (20%)**
  - Goal: familiarize yourself with deep learning libraries
  - Implement a method from a recent research paper and reproduce their results

- **Participation (20%)**
  - Attend classes!
  - Engage in class discussions
  - At the end of each module provide feedback
Academic Integrity

- Do not disclose exact solutions to members from other groups for assignments
  - High-level discussion is allowed
- Cite any external sources
- You can use ChatGPT/BARD/other AI assistants
  - But **add a note** explaining what you used it for and how you used it
Course Objectives

By the end of the course you will be able to…

1. Design, train, and evaluate deep neural networks
2. Apply deep learning techniques to solve real-world problems in computer vision, natural language processing, and other complex domains
3. Critically evaluate pros/cons of different model architectures
4. Read and understand research in deep learning
5. Understand the core design principles behind leading deep learning systems like GPT-4, DALL-E 2/3, and Stable Diffusion
Training Neural Networks

- Optimization algorithms - gradient descent, SGD, AdaGrad, Adam
- Learning rate scheduling
- Hyperparameter Optimization
- Regularization

Computer Vision

- Convolutional neural networks
- Different convolutional architectures - vanilla CNN, LeNet, ResNet, DenseNets
Natural Language Processing

- Word Embeddings
- Recurrent Neural Networks - RNNs/ LSTMs
- Attention and Transformers
- Large Language Models (LLMs)

**Explaining a Joke**

*Input:* Did you see that Google just hired an eloquent whale for their TPU team? It showed them how to communicate between two different pods!

https://arxiv.org/abs/2204.02311
Natural Language Processing

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Input: Did you see that Google just hired an eloquent whale for their TPU team? It showed them how to communicate between two different pods!

Model Output: TPUs are a type of computer chip that Google uses for deep learning. A "pod" is a group of TPUs. A "pod" is also a group of whales. The joke is that the whale is able to communicate between two groups of whales, but the speaker is pretending that the whale is able to communicate between two groups of TPUs.

https://arxiv.org/abs/2204.02311
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https://huggingface.co/blog/large-language-models
Graph Neural Networks

- Neural networks for data represented as graphs!
Modern Vision Networks

- Vision Transformers (ViTs)
- Vision Pre-Training
  - (Supervised, Self-supervised)
- Vision-Language Models

https://huggingface.co/spaces/vivien/clip
Real or Fake?

Generative Models

- U-Nets
- Variational Autoencoders (VAEs)
- Generative Adversarial Networks (GANs)
- Diffusion Models
- Multi-Modal Diffusion
Reinforcement Learning

Technique for an agent to learn in an interactive environment by testing different actions and obtaining feedback from its experiences.

- Markov Decision Process
- Q-learning/Deep Q-learning
- Policy Gradients
- Exploration strategies
- RL from Human Feedback
ARTIFICIAL INTELLIGENCE
A program that can sense, reason, act, and adapt

MACHINE LEARNING
Algorithms whose performance improve as they are exposed to more data over time

DEEP LEARNING
Subset of machine learning in which multilayered neural networks learn from vast amounts of data
McCulloch-Pitts Neuron

Computational model of a neuron that was proposed by Warren MuCulloch (neuroscientist) and Walter Pitts (logician) in 1943.
Perceptron (1957)

- Linear classifier, predecessor to Neural Network
- Trained with the perceptron update rule
- Invented @ Cornell University
  - First task: Recognize the Cornell “C” Logo
Multi-layer neural networks

- Multi-Layer Perceptron, Rosenblatt (around 1965)
- Alexey Grigoryevich Ivakhnenko 1965 Group Method of Data Handling (GMDH)
  - 1971 Eight Layer Neural Nets with skip connections!

- (1969) Minsky & Papert “killed” AI
- Burst huge expectation bubble
- Speech understanding / translation fails
- UK and US stop funding AI research

Backprop

- 1960 Henry J. Kelly Initial formulation in control theory (rocket science)
- 1962 Stuart Dreyfuss (use of chain rule)
- 1979 Seppo Linnainman (modern backdrop with automatic differentiation [not in context of neural nets])
- 1982 Paul Werbos proposes backprop for artificial Neural Networks in PhD thesis
- 1986 Rumelhart, Hinton, Williams (coin the term “back-propagation”) make the algorithm popular (published in Nature)
ConvNets

- 1979 Kunihiro Fukushima invents Neocognitron
  - Heavily inspired by human Visual Cortex
  - Alternates between Simple Cells / Complex Cells
  - Unsupervised
- 1986 Yann LeCun introduces BackProp to ConvNets for Handwritten Digits (creates MNIST)
Recurrent Neural Nets

- 1982 John Hopfield “Hopfield Networks”
- 1991 Sepp Hochreiter formulates Vanishing Gradient Problem
- 1997 S. Hochreiter and Jürgen Schmidhuber publish “Long Short-Term Memory” (LSTM)

Universal Approximation

- 1989 George Cybenko proofs universal approximation of single hidden-layer neural networks

- Also yields wide-spread believe that more than one layer is unnecessary
Summer of SVMs 1995-2008

- Mid 2000s ICML and NeuRIPS (NIPS) exclusively papers on non-neural network approaches
  - Mostly SVM, Graphical Models, Boosting
  - These algorithms are more efficient, easier to train / modify, have strong theoretical guarantees / frameworks
Neural Network Resurgence (2010s)

- Relentless effort by Hinton, Bengio, LeCun: Kept pushing Neural Nets when they were not cool - but did not join other communities (e.g. ICANN)
- Invent Deep Belief Nets in effort to attract experts in Graphical Models (mimics Graphical Models)
- Rename Neural Nets as “Deep Learning” (in effort to brand SVMs as “shallow”)
- Create ICLR as a venue to accept research on Neural Nets
- 2007 NeuRIPS Workshop on Deep Learning (rejected, changed to Hinton’s 60th birthday party)
- 2009 Fei-Fei Li creates ImageNet (after Caltech 4, 101, 256)
- 2012 Hinton’s deep network research creates AlexNet
The Era of Scale (2020-Present)

- GPT-3 introduced in 2020
  - “Language Models are Few-Shot Learners”
- Stable Diffusion released in 2022

https://stability.ai/stable-image
Public Perception of AI/ML

AI/ML winters

AI Excitement Fueled by A* Search
Backprop based NNs

Overpromise
Extreme Expectations

1st AI Winter
2nd AI Winter

Machine Learning
(Kernel Methods, SVMs)

Deep Learning
(ImageNet)

Foundation Models
(GPT-3)

???

https://medium.com/ersiliaio/beyond-the-hype-of-ai-ml-in-biomedicine-76c198c07467
Task: Predict whether it is winter from an image.
Thanks!

- If you have received a permission number
  - Enroll today if you’d like to take the course
- We will start sending out permission numbers to people on the waitlist later this week
- If you have not received a permission number and want to enroll
  - Come talk to us after class