

# Deep Learning

IE 534 Fall 2018

Instructor: Justin Sirignano

## Overview:

This course is an introduction to deep learning. Topics include convolution neural networks, recurrent neural networks, and deep reinforcement learning. The course will use TensorFlow to train models on GPUs.

Deep learning is computationally intensive. This course is supported by a computational grant for **50,000 GPU node hours**. This provides a unique opportunity for students to develop sophisticated deep learning models.

## Grading:

50% Homeworks

30% Midterm

20% Final Project

The 2 lowest homework grades are dropped.

## Prerequisites:

Python. Basic statistics, probability, and optimization. CS 446 (or equivalent) is recommended. Basic knowledge of Bash/Linux is recommended.

## TensorFlow, PyTorch, Linux/Bash, and MPI:

Lectures and tutorials will cover TensorFlow, PyTorch, Linux/Bash, and MPI. Example code will be provided to students. Students will learn how to use Distributed TensorFlow and Distributed PyTorch for parallelizing training of deep learning models across multiple GPU nodes. The OpenAI Gym environment for deep reinforcement learning will also be reviewed.

## Topics:

- Feedforward networks
- Convolution networks
- Backpropagation
- Stochastic Gradient Descent
- Hyperparameter selection and parameter initialization
- Optimization algorithms (RMSprop, ADAM, momentum, etc.)
- Second-order optimization (e.g., Hessian-free optimization)
- TensorFlow, PyTorch, automatic differentiation, static versus dynamic graphs, define-by-run

- Regularization (L2 penalty, dropout, ensembles, data augmentation techniques)
- Batch normalization
- Deep residual neural networks
- Dense networks
- Recurrent neural networks (LSTM and GRU networks)
- Video recognition (two-stream convolution network, 3D convolution networks, convolution networks combined with LSTM, optical flow)
- Generative Adversarial Networks
- Deep reinforcement learning (Q-learning, actor-critic, policy gradient, experience replay, double Q-learning, deep bootstrap networks, generalized advantage estimation, dueling network, continuous control, Atari games, AlphaGo)
- Distributed training of deep learning models (asynchronous stochastic gradient descent, parameter servers, synchronous stochastic gradient descent, asynchronous advantage actor-critic, MPI All-Reduce, Ring All-Reduce)
- Theory of deep learning (universal approximation theorem, convergence rate, and recent mathematical results)
- Convergence analysis of stochastic gradient descent, policy gradient, tabular Q-learning

### **Homeworks:**

See course website for a list of the homeworks.

### **Reading:**

A list of journal and conference papers will be provided to the class.

Textbook: “Deep Learning” by Goodfellow, Bengio, and Courville, MIT Press, 2017.

### **Examples of Final Projects in 2016, 2017:**

Driverless car, video recognition, text-to-image generation, automatic labeling and description of images, earthquake simulation analysis, laser guidance (LIDAR), deep reinforcement learning.