ECBM E4040
Neural Networks and Deep Learning

Introduction to the Course

Zoran Kostić
Columbia University
Electrical Engineering Department &
Data Sciences Institute

COLUMBIA ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Goals of the Course

Introductory course in Deep Learning (DL)

Train students in Deep Learning / Artificial Neural Networks:

- **Theory**
- **Architectures/Models and Methods**
- **Tools and Programming**
- **Data Acquisition**
- **Applications**

Instructors

Zoran Kostić, Ph.D.

Assoc. Prof. of Practice

Electrical Engineering Dept.

webpage

zk2172 (at) columbia.edu

Teaching Assistants

- **in courseworks and on the web**

Course Blueprint

Introduction: Course Logistics, Deep Learning Basics, Computing Resources

Background: Linear Algebra, Probability and Statistics, Numerical Computation

Machine Learning Basics and Algorithms

Deep Feedforward Networks

Back Propagation

Convolutional Neural Networks

Regularization

Optimization

Recurrent and Recursive Nets

Practical Methodology

Autoencoders

Contemporary Topics in Deep Learning

Outline of the Introduction

1. Introduction to Course E4040

- **Goals of the Course**
- **Course Blueprint**
- **Logistics**

2. Introduction to Deep Learning

- **Biological Neural Networks (NN)**
- **What is Deep Learning (DL)**
- **Historical Trends in DL**
- **Programming Tools for DL**

3. Introduction to Computing Resources

Student Prerequisites / Qualifications

Required

- **Linear algebra**
- **Probability and statistics**
- **Programming experience**

Desirable

- **Machine learning (or)**
- **Detection and estimation (or)**
- **Pattern recognition**

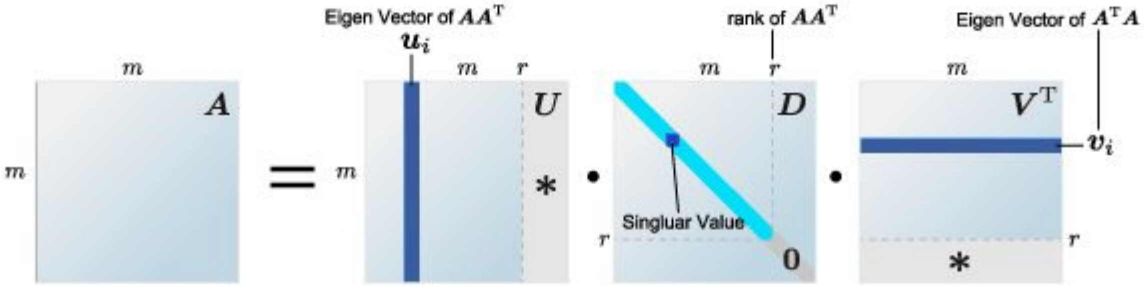
Desirable - Computational

- **Linux, python**
- **Cloud computing**
- **Parallel computing**

The course will use, test and teach some material from desirable category.

Knowledge of Linear Algebra - Samples

$$A = UDV^{\mathrm{T}}$$



Singular Value Decomposition (from https://www.numtech.com/systems/)

$$\frac{\mathrm{d}}{\mathrm{d}x}A^+(x) = -A^+\left(\frac{\mathrm{d}}{\mathrm{d}x}A\right)A^+ \; + \; A^+A^{+\mathrm{T}}\left(\frac{\mathrm{d}}{\mathrm{d}x}A^{\mathrm{T}}\right)(I - AA^+) \; + \; (I - A^+A)\left(\frac{\mathrm{d}}{\mathrm{d}x}A^{\mathrm{T}}\right)A^{+\mathrm{T}}A^+$$

https://en.wikipedia.org/wiki/Moore%E2%80%93Penrose_pseudoinverse

Knowledge of Probability & Statistics - Sample

Our belief about $\boldsymbol{\theta}$ is given by the posterior distribution via Bayes rule:

$$p(\boldsymbol{\theta}|x^1, ..., x^m) = \frac{p(x^1, ..., x^m|\boldsymbol{\theta})p(\boldsymbol{\theta})}{p(x^1, ..., x^m)},$$

where $p(x^1, ..., x^m|\boldsymbol{\theta})$ is the likelihood of observing the data samples $\{x^1, ..., x^m\}$ given $\boldsymbol{\theta}$.

Knowledge of Programing

++

Class Resources

Lectures

Recitations

Office Hours

Courseworks

Webpages

Bitbucket

Google drive

Piazza discussion site

Technology resources

Educational resources

Deep learning news

Evaluation / Grading

3 or 4 homeworks (tentative 40%):

- **Theory: concepts & analytical**
- **Programming/DL models**

Exam (tentative 25%):

- **Theory: DL concepts and models, analytical**
- **DL pseudo code**

Reading assignments

Project (tentative 30%):

- **Groups of up to 3 students**
- **12 slides - poster presentation**
- **Report, conference-like**
  - **two-column, 4+ pages**
- **Code in bitbucket/github**
- **Webpage (optional)**

DL dataset collection (TBD)

Kaggle contribution

Student's class contribution (TBD)

2016 Projects

- Striving for Simplicity: The All Convolutional Net
- A Combined Semi-supervised Learning mechanism for Video Data via Deep Learning
- A Neural Algorithm of Artistic Style
- Adieu features? End-to-end speech emotion recognition using a deep convolutional recurrent network
- Colorful Image Colorization
- Deep Networks with Stochastic Depth
- Highway Networks
- Image Super-Resolution Using Deep Convolutional Networks
- Learning to Protect Communications with Adversarial Neural Cryptography
- Singing Voice Separation from Monaural Recordings Using Deep
- Recurrent Neural Networks
- Spatial Transformer Networks
- Spoken Language Understanding Using Long-Short Term Memory Neural Networks
- Striving for Simplicity: The All Convolutional Net
- Unsupervised Representation Learning with Deep Convolutional Generative Adversarial Networks

2017 Projects

A Neural Algorithm of Artistic Style
BinaryConnect: Training Deep Neural Networks with Binary Weights during Propagations
Composing music with recurrent neural networks
Deep Learning Face Representation from Predicting 10,000 Classes
Deep Learning in Finance; Deep Portfolio Theory
Deep Networks with Stochastic Depth
DeepDriving: Deep Learning for Autonomous Driving
Depth Map Prediction from a Single Image using a Multi-Scale Deep Network
Draw: A Recurrent Neural Network for Image Generation

Long Short Term Memory Networks for Anomaly Detection in Time Series
Multi-digit Number Recognition from Street View Imagery using Deep Convolutional Neural Networks
Predicting HIV Risk Factors From Unstructured Clinical Text
Richer Convolutional Features for Edge Detection
Spectral Representations for Convolutional Neural Networks
Understanding Deep Learning Requires Rethinking Generalization
Using Convolutional Networks and Satellite Imagery to Identify Patterns in Urban Environments at a Large Scale

2018 Projects

A deep learning framework for financial time series using stacked autoencoders and LSTM

A Neural Algorithm of Artistic Style

A Neural Representation of Sketch Drawings

Adversarial Variational Bayes: Unifying Variational Autoencoders and GANs

Backprop KF: Learning Discriminative Deterministic State Estimators

Deep contextualized word representations

Dynamic Routing Between Capsules

Gesture Recognition

Learned in Translation: Contextualized Word Vectors

Universal Style Transfer via Feature Transforms

Maximum Classifier Discrepancy for Unsupervised Domain Adaptation

Multi-Digit Number Recognition from Street View Imagery Using Deep Convolutional Neural Networks

Neural Networks for Automated Essay Grading

Parallel Multi-Dimensional LSTM,With Application to Fast Biomedical Volumetric Image Segmentation

PixelGAN Autoencoders

Prevention of catastrophic forgetting in Neural Networks for lifelong learning

Learning a Probabilistic Latent Space of Object Shapes via 3D Generative-Adversarial Modeling

Semantic Image Inpainting with Deep Generative Models

Unsupervised Image-to-Image Translation Networks

Self-Assessment

- **Do the first homework focused on tool setup and introductory programming**
  - That will help you ascertain the programming knowhow and expected workload needed to do the rest of the homeworks and the project
  - If you have programming/tool difficulties with the homework, carefully evaluate whether you will have enough time to acquire the programming knowledge.
- **Consider how solid is your preparatory theoretical knowledge**
  - The exam will use applied mathematical concepts from linear algebra, probability and statistics, machine learning, and deep learning. Some of the background material will be covered in this course, some will be assumed from previous courses. Asses if you will have time to acquire knowledge of the background material and/or do a detailed refresh.
  - The exams test deep learning theory, concepts, algorithms and model understanding.
- **Review sample projects from previous years**

If you have concerns on any of the above, you are strongly advised to drop the class.

Academic Integrity

Each student has to do his/her own work. Plagiarism and cheating of any form is forbidden, including code and paper copying between students and from the web.

http://www.ee.columbia.edu/academic-integrity-2

References and Acknowledgments

Required Book

- Goodfellow, Y. Bengio and A. Courville, "Deep Learning," MIT Press, 2016
  - Free online version of the book http://www.deeplearningbook.org/
  - For purchase: https://mitpress.mit.edu/books/deep-learning
  - Hardcover, November 2016, ISBN: 9780262035613
  - eBook, November 2016, ISBN: 9780262337434

NVIDIA DL Teaching Kit

- https://developer.nvidia.com/teaching-kits

Lecture material by bionet group / Prof. Aurel Lazar

- (http://www.bionet.ee.columbia.edu/)

Backup Slides

Various