M2177.0043 Introduction to Deep Learning

Lecture 1: Introduction

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Outline

For those who are waitlisted

- Following people should submit the override form to Seohyun Park in CSE office:
  - Anyone who's majoring in Computer science, Electrical engineering, Mathematics, Statistics, Liberal studies.
  - Or anyone who's minoring in Computer science

Logistics

- Teaching Staff: (Instructor) Prof. Hyun Oh Song, (TAs) Wonho Choo, Janghyun Kim
- Lectures: Tuesdays & Thursdays 5:00-6:15 PM
- Material a bit different from last years course. Minimal review of probability & linear algebra. More on the underlying principles behind the state of the art machine learning.

Logistics

- Textbook: No official textbook. (optional-1) Deep learning-Ian Goodfellow and Yoshua Bengio and Aaron Courville-MIT Press-2016, free online; (optional-2) Introduction to Probability by Bertsekas and Tsitsiklis
- Prerequisites: Students are expected to have taken courses in linear algebra, multivariate calculus, and probability and statistics as prerequisites. Also familiarity with Numpy or a related matrix-oriented programming language is strongly recommended.
- Course website: On ETL. I strongly recommend everyone to engage questions and discussions in the Q&A board on ETL.

Grading

- Homeworks should be submitted on ETL as LaTex generated pdf files. Use the LaTex template posted on ETL.

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- Homeworks: Problems will be posted on ETL. No late homeworks will be accepted (no exceptions). There's no need to submit doctor's notes, conference travel invitations, etc. We will drop your lowest homework instead.

$$\texttt{total\_hw\_score} = \frac{1}{n-1}\left(\sum_{i}^{n} \texttt{score}(i) - \min_{i} \ \texttt{score}(i)\right)$$

Collaboration

- Collaboration on solving the homework is allowed. Discussions are encouraged.
- However, you should think about the problems on your own. If you do collaborate with someone or use a book or website, you are expected to write up your solution independently.

Outline

What is this course about?

- This class is not about learning how to use Tensorflow/Caffe/Theano/Torch.
- The goal of this class is to provide thorough grounding in the algorithms, mathematics, theories, and the underlying intuition needed to do in-depth research and applications in machine (shallow and deep) learning.

Machine learning

- Study of algorithms that learn from the data x

$$x \longrightarrow \boxed{f(x)} \longrightarrow y$$

Supervised learning

- Binary/Multiclass classification
  Given x find y in $\{1, \ldots, K\}$.
- Regression
  Given x find y in $\mathbb{R}^d$
- Sequence annotation
  Given sequence $x_1, \ldots, x_n$, find $y_1, \ldots, y_m$
- Prediction
  Given x_t and $y_1, \ldots, y_{t-1}$, find y_t

Example: Classification

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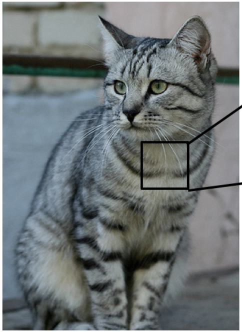
(assume given set of discrete labels)
{dog, cat, truck, plane, ...}

$\longrightarrow$ cat

Example: Classification



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What the computer sees

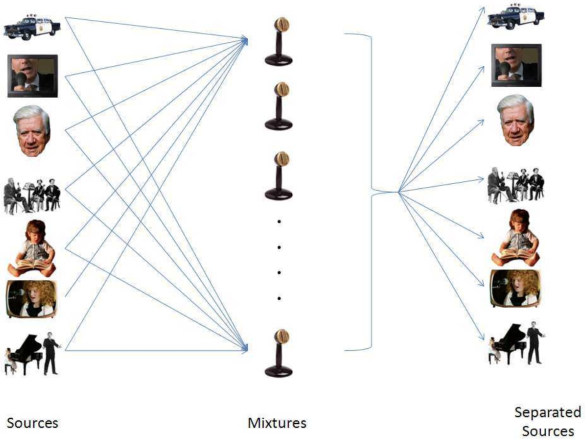
An image is just a big grid of numbers between [0, 255]:

e.g. 800 x 600 x 3
(3 channels RGB)

Unsupervised learning

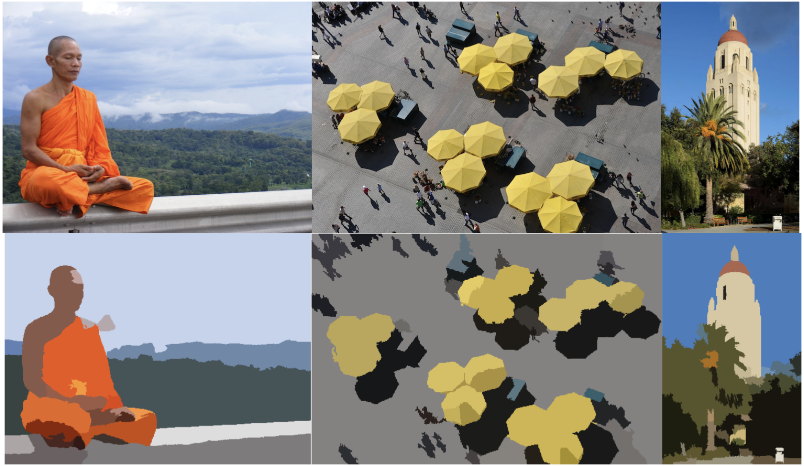
- Clustering
  Find a set of prototypes representing the data
- Sequence Analysis
  Find a latent casual sequence for observations (HMM, Kalman Filter, etc)
- Independent components / dictionary learning
  Find a set of factors for observation
- Novelty detection
  Find the odd one out

Example: Independent Component Analysys

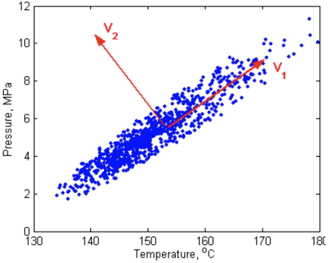


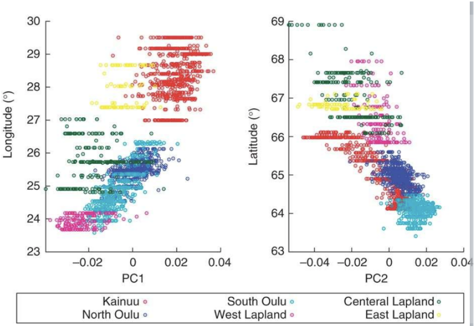
find them automatically

Example: Normalized Cuts



Example: Principal component analysis



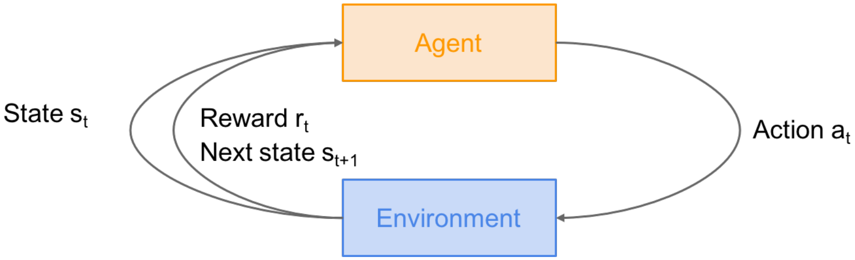


[Variance component model to account for sample structure in genome-wide association studies](), **Nature Genetics 2010**

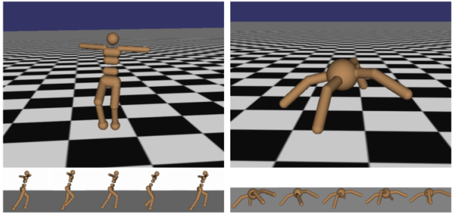
Interaction with Environments

- Online
  Observe x_t, predict $f(x_t)$, observe y_t
- Active learning
  Query y_t for x_t, improve model, pick new x
- Bandits
  Pick arm, get reward, pick new arm. Also viewed as one-state or stateless reinforcement learning
- Reinforcement learning
  Take action, environment responds, take new action

Reinforcement learning



Robot locomotion



Objective: Make the robot move forward

State: Angle and position of the joints
Action: Torques applied on joints
Reward: 1 at each time step upright + forward movement

Atari Games

[Mnih et al. NIPS Workshop 2013; Nature 2015]

Objective: Complete the game with the highest score

State: Raw pixel inputs of the game state
Action: Game controls e.g. Left, Right, Up, Down
Reward: Score increase/decrease at each time step

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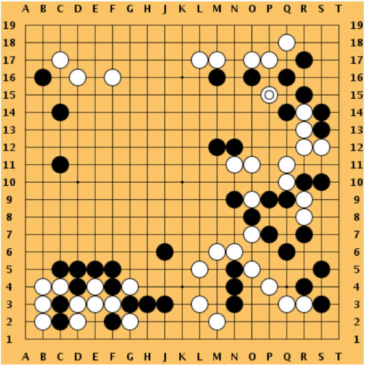
- How many possible configurations of image states are there?

Go



Objective: Win the game!

State: Position of all pieces
Action: Where to put the next piece down
Reward: 1 if win at the end of the game, 0 otherwise

- How many possible configurations of board states are there?

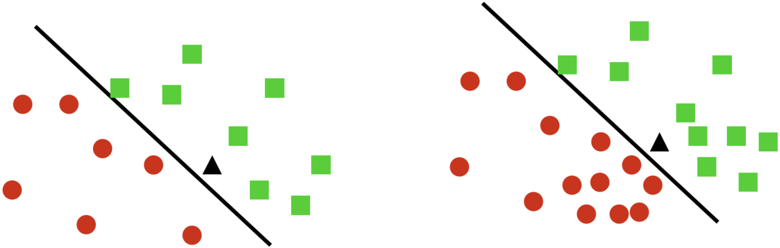
Discriminative vs. Generative

- Discriminative models
  Estimate $p(y|x)$ directly. Often leads to better convergence and simpler solutions.

- Generative models
  - Estimate the joint distribution over $p(y,x)$.
  - Use conditional probability to infer $p(y|x) = \frac{p(y,x)}{p(x)}$.
  - Can use $p(x)$ to generate data.

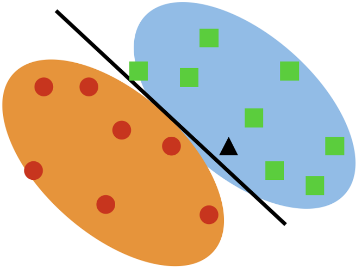
Discriminative

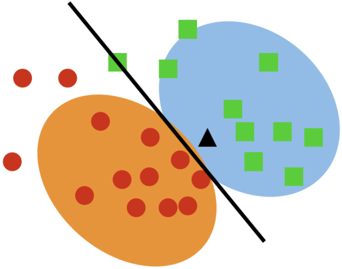
- Only care about estimating the conditional probabilities.
- Very good when underlying distribution of data is really complicated.



Generative

- Model observation $p(x, y)$ first.
- Then infer $p(y|x)$.
- Good for missing variables.





Outline

Tentative Agenda

- Score functions and Loss functions
- Theoretical analysis of optimization algorithms
- Introduction to neural networks
- Convolutional neural networks
- Practical issues in training networks
- CNN architectures
- Recurrent networks
- Deep metric learning
- Generative models - GANs, VAEs
- Disentanglement
- Adversarial attacks and defense
- Data mixup augmentation
- Network pruning and efficient inference
- Deep reinforcement learning

General tips

- Learning how to learn coursera (haven't checked but heard it's good) https://www.coursera.org/learn/learning-how-to-learn
- Take the homeworks seriously and start early.
- Engage in discussions with your peers.
- Actively utilize the Q&A board on ETL.