Introduction

Industrial AI Lab.
Introduction

• 2018 - present: POSTECH
  – Industrial AI Lab.

• 2013 - 2017: UNIST
  – iSystems Design Lab.

• 2010, Ph.D. from the University of Michigan, Ann Arbor
  – S. M. Wu Manufacturing Research Center
  – The Center of Intelligent Maintenance Systems (IMS)

• 2008, M.S. from the University of Michigan, Ann Arbor

• 2005, B.S. of Electrical Engineering from Seoul National University
• 2001, B.S. of Mechanical Engineering from Seoul National University
Data Science
Machine Learning/Deep Learning
Artificial Intelligence

Industrial AI
Machine Learning and Deep Learning

(Big) Data → Information Knowledge

IoT Sensors → First Principles

Engineered Systems
Course Info

• Machine learning
  – Linear algebra
  – Optimization
  – Statistical and probabilistic approaches

• Python in class and assignments
  – Used a lot
  – Provide all necessary .py codes for a class

• Evaluation
  – Two exams (30% + 35%)
  – Many assignments (25%)
  – Class participation (10%)
Lecture Materials

- All lecture materials are already available at
- Lecture video will be posted at YouTube (but in Korean)

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**MACHINE LEARNING AND DEEP LEARNING**

Note: Lecture slides are best viewed in Chrome.

### Machine Learning

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What is Machine Learning

• Draw a meaningful conclusion, given a set of data (observation, measurement)

• In 1959, Arthur Samuel defined machine learning as a
  – “Field of study that gives computers the ability to learn without being explicitly programmed”
  – Often hand programming not possible
  – Solution? Get the computer to program itself, by showing it examples of the behavior we want! This is the learning approach of AI
  – Really, we write the structure of the program and the computer tunes many internal parameters
What is Machine Learning?

• Many related terms:
  – Pattern recognition
  – Neural networks → Deep learning
  – Data mining
  – Adaptive control
  – Statistical modeling
  – Data analytics / data science
  – Artificial intelligence
  – Machine learning
Learning: Views from Different Fields

• Engineering
  – Signal processing, system identification, adaptive and optimal control, information theory, robotics, ...

• Computer science
  – Artificial intelligence, computer vision, ...

• Statistics
  – Learning theory, data mining, learning and inference from data, ...

• Cognitive science and psychology
  – Perception, movement control, reinforcement learning, mathematical psychology, ...

• Economics
  – Decision theory, game theory, operational research, ...
Course Roadmap

• Supervised Learning
  – Regression
    • Linear, Nonlinear (kernel), Ridge ($L_2$ norm regularization), Lasso ($L_1$ norm regularization)
  – Classification
    • Perceptron, SVM, Logistic regression, Bayesian classifier

• Unsupervised Learning
  – Clustering
    • k-means, Gaussian Mixture Model (GMM)
  – Dimension reduction
    • Principal Component Analysis (PCA)

• Probabilistic Machine Learning
  – Parameter estimation (MLE and MAP)
Course Roadmap

Multivariate Analysis

Optimization

Linear algebra
- vector
- matrix
- linear algebra basics
- low rank approximation
- SVD
- matrix

Statistical approach
- sample mean and variance
- multivariate covariance
- central limit theorem

Probabilistic approach
- random vector
- conditional pmf
- marginal pmf
- covariance and correlation
- affine transformation
- sum of iid
- Bayes rule
- prior prob
- MAP
- maximum-likelihood
- random vector
- classifiation
- perception
- basic
- residual
- norms
- linear function
- nonlinear function
- maximum likelihood
- estimation
- maximum likelihood
- Fisher linear discriminant
- MAP
- Bayesian classification
- linear and quadratic decision boundaries
- logistic regression

Machine learning
- mean and covariance
- ellipsoids
- signal smoothing
- quadratic programming
- least squares
- integer programming
- support vector machine
- sparsity & data compression
- optimization problems
- fitting with different norms
- logistic regression
- support vector machine
- sudoku

Gaussian distribution
- mean and covariance
- marginal
- linear transformation of Gaussian
- conditional pdf of Gaussian
- linear model

CVX tool
- convex optimization
- standard representation

Course Roadmap

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Required Mathematical Tools

• Linear algebra
  – Vector and Matrix
  – $Ax = b$
  – Projection
  – Eigen analysis

• Optimization
  – Least squares
  – Convex optimization (cvx or cvxpy)

• Statistics
  – Law of large numbers, central limit theorem
  – Correlation
  – Monte Carlo simulation

• Probability
  – Random variable, Gaussian density distribution, conditional probability
  – maximum likelihood (MLE), maximum a posterior (MAP), Bayesian thinking
Deep Learning

• Deep Learning will not be covered in this course

• I plan to open a new graduate course for deep learning next semester (2018 Fall)

• For those who are eager to learn about deep learning,
  – Short course tutorials
  – Installation and TensorFlow
What Will We Cover?
Data Fitting or Approximation (Regression)

- Statistical process for estimating the relationships among variables
Classification

• The problem of identifying to which of a set of categories (sub-populations) a new observation belongs, on the basis of a training set of data containing observations (or instances) whose category membership is known.
Dimension Reduction

• Multiple Sensors + Principal Components
• the process of reducing the number of random variables under consideration, and can be divided into feature selection and feature extraction.
Industrial AI lab at POSTECH

• Vision
  – AI for mechanical engineering
  – AI for industrial applications
  – AI for manufacturing

• Some research activities in our lab
Deep Learning of Things (DoT)
Sound Signal Classification

• Inspecting a rotating fan
  – Sampling frequency: 51.2 kHz
  – Duration: 8 sec ~ 9 sec

– NG sound

– OK sound
Real-time Human Detection

99.98%
Visualizing and Understanding Convolutional Networks
Privacy-preserving Human Detection
Artistic Style Transfer
Human Motion Recognition

Label: Crouching
Predict: --
Make it Stable (Robust)

• Control: PID
• From open-loop to closed-loop systems
Reinforcement Learning on Unicopter

Learning from Scratch

AlphaGo Zero

Learned
Make-up Class

• 02/26 (next Monday)
  – TA will discuss
    • python installation, ipython notebook, basic python, CVXPY

• 03/21

• 04/02 (not sure yet)