Syllabus for IE481: Special Topics in Industrial Engineering I (Data-Driven Decision Making and Control)

Instructor

Jinkyoo Park
Office : E2-1, #4212
Email : jinkyoo.park@kaist.ac.kr
Office hours: Tue/Th: 2:00-4:00 pm (other times are available by appointment by email)

Time/Location

Time: Tue/Th from 10:30 – 11:45 pm
Location : (E2) Industrial Engineering & Management Bldg., Lecture room 2 (#1119)

Course TA

TBD

Prerequisites

- IE241 Engineering Statistics or similar courses
- IE331 Operations Research I or similar courses

Textbook

Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction,* MIT Press, 1998
(available: http://webdocs.cs.ualberta.ca/~sutton/book/the-book.html)

References (advanced)

- Andrew Gelman, *Bayesian Data Analysis, CRC Press*
- Hastie, T., Tibshirani, R., Friedman, J. (2001). The Elements of Statistical Learning. New York: Springer
- Mykel J. Kochenderfer, *Decision-making Under Uncertainty: Theory and Application*, MIT Press, 2015

Overview

With advancements in sensing technologies and Big data analytics, lots of attention is drawing to intelligent systems that can automate data analysis and decision making for improving the system performances. To realize the intelligent systems, it is imperative to develop an efficient algorithm that can derive the optimum decisions considering model uncertainty, state uncertainty and environment uncertainty.

This course provides an overview of various decision-making methodologies in both modeling and computational perspectives. The course mainly covers probabilistic (Bayesian) modeling approaches, which is advantageous in modeling uncertainties encountered in various decision-making problems and in combining the learning (exploration) and the optimization (exploitation) in a single framework.

Following an introduction to probabilistic models and decision theory, the course will cover various decision-making methodologies for various circumstances that can be roughly classified as: (1) single-agent, single-stage decision-making, (2) single-agent, multi-stage decision-making, and (3) multi-agent, single-stage decision-making. Topics include Bayesian statistics, Bayesian Network, influential diagram, bandit problems, Markov decision processes, and game theory.

Objectives

Upon successful completion of the course, you are able to

- *understand* various mathematical models describing decision making problems.
- *formulate* real-world decision making problems in a mathematical form.
- *implement* key algorithms and approaches to solving various decision making problems.
- *Interpret* the results of decision-making problems.

Topics (tentative)

1. Bayesian Modeling and Inference (3 weeks)
- Probability distributions
- Prior, Likelihood, and Posterior
- Conjugate models
- Hierarchical Modeling
- Elements of Computational Bayesian Statistics

2. Single-agent, single-stage decision-making (3 weeks)
- Bayesian regression
- Bayesian classification
- Bayesian Network
- Influential Diagram

3. Single-agent, Multi-stages decision-making (6 weeks)
- Bandit problem
- Bayesian Optimization
- Markov Decision Process (MDP)
- Dynamic Programming
- Reinforcement Learning
  - Monte Carlo Methods
  - Temporal Difference Methods
  - Bayesian Reinforcement Learning

4. Multi-agent, Single-stage decision-making (2weeks)
- Basics of game theory
- Learning in Repeated Games

Evaluations (tentative)

- 5 sets of homework (25%)
- Midterm exam (20%)
- Final exam (30%)
- Final project (20%)
- Attendance and class participation (5%)

Projects

The objective of the project is to encourage students to define their own problems of interests and formulate them in a formal mathematical way. The topic should be related to the general theme of the course. As part of the project you should:

- *formulate* a target problem
- *apply* a decision making methodology to solve the formulated problem
- *present* the results to other people