IE481& IE801
Special Topics in Industrial Engineering I & II
(Game Theory and Multi-Agent Reinforcement Learning)

Instructor

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Office hours: Fri: 1:00-4:00 pm (other times are available by e-mail appointment)

Time/Location

Time: Mon & Wed: 10:30 – 12:00
Location : Bldg. E2 #1120

Course TA

TBD

Prerequisites (not mandatory)

- IE481 Data-driven decision making and control
- Experience on Deep Learning and Reinforcement Learning would help. The knowledge on deep learning and reinforcement learning is required for understanding and implementing multi-agent reinforcement learning (MARL) at the end of the course.

Textbook

- Not required

References

- Yoav Shoham and Kevin Leyton-Brown, *Multiagent Systems*, Cambridge, 2009
- Tamer Basar and Geert Jan Olsder, Dynamic Noncooperative Game Theory (2^{nd}), SIAM
- Steven Tadelis, Game Theory: An Introduction, Princeton
- Dario Bauso, Game Theory with Engineering Applications, Siam

Overview

As engineering systems become highly complicated and distributed, it becomes challenging to understand the collective and interactive behavior of such systems. The control problem of a multi-agent system has drawn much attention recently due to the practical and potential applications in intelligent transportation, smart grid, smart factory, etc. Advances in deep learning also contribute to multi-agent modeling and control by providing efficient means of flexible and extensive modeling power.

A multi-agent system is composed of a set of independent agents that interact with each other in a shared stochastic environment. Since the agents in a multi-agent system lack full information of dynamic environment and other agents' strategies, learning decision-making strategy (policy) in a multi-agent system is much more challenging than in a single agent system.

This course provides an essential and fundamental knowledge required for understanding multi-agent systems and deriving decision-making strategies. The two primary subjects of the course are (1) game theory and (2) data-driven decision-making (e.g., machine learning or reinforcement learning). This course first provides an overview of game theory in both modeling and computational perspectives. Based on the analytical framework, the course will discuss how learning concepts can be used with game-theory modeling techniques to derive the optimum operational strategies for a multi-agent system. The final goal of the course is to provide the fundamentals on modern multi-agent reinforcement learning algorithms based on deep neural network function approximations.

Objectives

- Understand various modeling approaches in game theory
- Understand data-driven decision making and control approaches
- Understand how learning concepts can be employed in game theory modeling
- Understand the concept of multi-agent reinforcement learning
- Formulate real-world problems with multiple decision makers using game theory

Topics (tentative)

Part 1: Classical Game Theory

1. Static Games of Complete Information
2. Dynamic Games of Complete Information
3. Static Game of Incomplete Information
4. Dynamic Games of Incomplete Information
5. Learning in Repeated Game

Part 2: Data-Driven Control for Multi-Agent Systems

6. Markov Decision Process and Value Based Reinforcement Learning
7. Optimal Control and Policy Based Reinforcement Learning
8. Stochastic Game and Value Function Based Multi-Agent Reinforcement Learning
9. Cooperative Dynamic Game (Dec-POMDP)
10. Non Cooperative Dynamic Game
11. Deep Learning based MARL for Cooperative Game (CTDE-Principle)
12. Deep Learning based MARL for Cooperative Game (Paper Reviews)
13. Deep Learning based MARL for Noncooperative Game

Evaluations (tentative)

- 4 sets of homework (20%)
- Midterm exam (30%)
- Final project (40%)
- Class Participation (10%)

Projects

There are two types of final project that a student can choose between.

First project type: MARL code development
First project is to develop an MARL algorithm to play a StarCraft 2 minigame. The objective of this project is to have students to experience the developing process of MARL algorithm to tackle a complex dynamic game. For the project, students are allowed to utilize the MARL environment for StarCraft 2 minigame and PyTorch based MARL code environment:

SC2 minigame environment: https://github.com/oxwhirl/smac
PyTorch based MARL environment: https://github.com/oxwhirl/pymarl/

Second project type: Writing a research paper on Game theory related problem
Second type of project is to write a short research paper on Game theory related topic. 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
- *analyze* and *interpret* the results obtained
- *present* the result and derived insights to other people