Contact Information

Instructor: Paat Rusmevichientong (E-mail: rusmevic@marshall.usc.edu)
Office: BRI 400F
Office Hours: TBD and by appointment. The Zoom link is available on Blackboard.

Course Description and Overview

Real-time and sequential decision-making are possibly the fastest growing areas in modern operations management and operations research. Historically, these fields focused on “classical” applications such as inventory management with huge product catalogues. More recently, however, increased data availability and computational power have spurred exciting new applications of these techniques to matching markets, self-driving cars, artificial intelligence, and e-commerce. These new application arenas raise new challenges for researchers and practitioners alike.

This course is an advanced introduction to the fundamental methods in dynamic optimization and optimal control that underlie these real-time decision-making systems. The first half of the course focuses on classical dynamic optimization and optimal control problems where state spaces are small enough to be computationally tractable and the system dynamics are fully known. With this foundation, in the second half of the course, we introduce reinforcement learning and approximate dynamic programming. These techniques treat dynamic optimization problems where state spaces are not tractable and/or the dynamics of system are unknown. In these settings, we often have to learn about the system and make good decisions for the system simultaneously.

Throughout, we focus on rigorous theory and algorithmic development, motivating fundamental questions and results through relevant applications. The goal is to equip doctoral students with the skills to begin their own novel research in this domain.

A rough overview of the course is:

Part I (Weeks 1 – 3): Dynamic optimization formulations and problem-specific examples from supply chain, revenue management, and other applications areas. Examples may include myopic policies in optimal stopping, base stock and (s,S) policies in inventory control, nested protected level in capacity allocation, linear policies in linear quadratic control, and others.

Part II (Weeks 4 – 8): Exact algorithms for problems with tractable state spaces. We will cover value iteration, policy iterations, and linear programming methods. We will also study the interchange argument and optimality of index policies in the classical multiarmed bandit problem.
Part III (Weeks 9 – 13): Reinforcement learning and approximate dynamic programming. We cover some of the most fundamental algorithms of modern reinforcement learning and approximate dynamic programming. Examples may include regret minimization in the bandit problem, asynchronous value iteration, optimistic exploration, convergence of policy gradient methods, and approximate linear optimization. We will also cover recent applications of approximate dynamic optimization to revenue management applications.

Part IV (Weeks 14 – 15): Full-time work on final projects.

Prerequisites: Familiarity with linear algebra, real analysis, and Markov chains are strongly recommended as prior preparation for this course. Because this is a doctoral course, students are also expected to have substantive mathematical maturity and familiarity with proof-based mathematics. Students concerned about their background should reach out to the professor to discuss.

Class Schedule: Thursday 11am – 1:50pm @ HOH 114

Textbooks:

Grading: Participation 10%, Homework 15%, Midterm 35%, and Final Project 40%

- Your participation grade is based in part on class attendance, being prepared for class, and constructive participation during class, including answering questions and contributing to discussions in class. The final participation score is at the discretion of the instructor, but it is my hope that everyone receives full participation credits.
- Homework consists of problem sets that are distributed throughout the semester. Since there is no TA for the course, I will review all of the homework submissions myself, but we will also discuss the homework solutions in class.
- The midterm exam is open book and open notes.

Project

You need to complete a project on a course-related topic of your choice. The project entails choosing a topic related to the subject of this class, writing a project report, and delivering a short presentation during the final exam week. You are required to discuss with the instructor beforehand about the topic you have in mind. There are two types of projects:
1) Theoretical: Read and report on 5-6 papers in the area. This involves understanding the papers deeply and evaluating them critically. Include not just a synthesis of the material you read, but also your own thoughts on possible directions for further research, possible extensions, etc.

2) Applied: Pick a particular problem that can be formulated as an MDP problem and implement one or more computational approaches to solve it. You may focus on the problem itself (that is, compute solutions for variants of the problem and develop some insights), or on an assessment of computational methods (try different algorithms and compare their performance).

You can work by yourself or in a team. Each team will consist of at most 2 students.

**Format and Length:** The final paper should be written in 12pt font, single space, single column, and should be at most 15 pages in length, including figures. The length restriction is intended to help you focus on delivering a crisp message. On the other hand, you can include an appendix with additional material, such as long technical arguments, if you think these are necessary.

**Deadlines:**

Week of 3/9: Mandatory first meeting with individual teams to discuss project topics. You are strongly encouraged to talk with me much earlier in the semester, well before 3/9, about possible project ideas.

Thursday 3/30: Two-page project proposal is due in class. Ideally, the proposal should contain preliminary results that your team has obtained on this project.

Week of 4/27: Mandatory 2nd meeting with individual teams to discuss project progress.

Monday 5/8 @ 5pm: An electronic copy of your team’s final paper and presentation are due. Please email both of them to me by 5pm on 5/8.

Tuesday 5/9 from 11am-1pm: Presentation of your project. This is the official time slot for the final examination.

**Project Grading:**
- Two mandatory meetings: 3%
- Project proposal: 7%
- Final Paper: 25%
- Final Presentation: 5%
**Tentative Course Outline**

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<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Readings &amp; Assignments</th>
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<tbody>
<tr>
<td>1</td>
<td>Introduction to DP and Principle of Optimality</td>
<td>B1: Sections 1.2-1.3</td>
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<tr>
<td>2</td>
<td>Inventory Applications</td>
<td>B1: Section 4.2&lt;br&gt;<strong>Due: HW #1 on 8/31</strong></td>
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<td>3</td>
<td>Applications in Revenue Management and Optimal Stopping</td>
<td>B1: Section 4.4 and Instructor’s Notes</td>
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**Part I: Dynamic programming formulations and problem-specific examples**

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<tr>
<th>Week</th>
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<tbody>
<tr>
<td>4</td>
<td>Infinite-Horizon MDPs with Discounted Rewards and Value Iteration</td>
<td>B2: Section 1.2&lt;br&gt;<strong>Due: HW #2 on 9/14</strong></td>
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<td>5</td>
<td>Policy Iteration</td>
<td>B2: Section 2.2 – 2.3</td>
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<td>6</td>
<td>Additional Solution Techniques</td>
<td><strong>Due: HW #3 on 9/28</strong></td>
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<td>7</td>
<td>Review and Midterm</td>
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<td>8</td>
<td>Multiarmed Bandit: Optimality of Gittins’ Indices</td>
<td>B2: Section 1.3 and Instructor’s Notes</td>
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**Part II: Exact algorithms for problems with tractable state spaces**

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<tr>
<th>Week</th>
<th>Topic</th>
<th>Readings &amp; Assignments</th>
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<tbody>
<tr>
<td>9</td>
<td>Upper confidence bounds in regret minimization for the bandit problem. Connections to Gittins’ Indices</td>
<td><strong>Due: 1st meeting with individual teams to discuss project ideas</strong></td>
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<td>Spring Break (3/12 – 3/19): No Class</td>
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<tr>
<td>10</td>
<td>Value Function Approximation and Applications to Optimal Stopping</td>
<td>B2: Section 6.1 + notes</td>
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<td>11</td>
<td>Policy gradient methods and its convergence</td>
<td><strong>Due: 2-page project proposal on 3/30</strong></td>
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<td>12</td>
<td>Linear Programming for Approximate DP</td>
<td>B1: Section 6.6</td>
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<tr>
<td>13</td>
<td>Approximate DP in operations management</td>
<td>Instructor’s Notes</td>
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**Part III: Foundation of reinforcement learning and approximate dynamic programming: Techniques for problems with intractable state spaces and parameter uncertainties**

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<tr>
<th>Week</th>
<th>Topic</th>
<th>Readings &amp; Assignments</th>
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<tbody>
<tr>
<td>14</td>
<td>No class. Full-time work on the project</td>
<td><strong>Due: 2nd meeting with individual teams to discuss project progress</strong></td>
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<tr>
<td>15</td>
<td>No class. Full-time work on the project</td>
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**Final Project Presentation:** Tuesday, May 9, from 11am – 1pm. This is the official time slot for our final examination.

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ADDITIONAL INFORMATION

USC Statement on Academic Conduct and Support Systems

Academic Conduct: Plagiarism – presenting someone else’s ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, “Behavior Violating University Standards” https://policy.usc.edu/scampus-part-b/. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct. http://policy.usc.edu/scientific-misconduct.

Support Systems

Student Counseling Services (SCS) - (213) 740-7711 – 24/7 on call: Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. https://engemannshc.usc.edu/counseling/

National Suicide Prevention Lifeline - 1-800-273-8255: Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. http://www.suicidepreventionlifeline.org

Relationship & Sexual Violence Prevention Services (RSVP) - (213) 740-4900 - 24/7 on call: Free and confidential therapy services, workshops, and training for situations related to gender-based harm. https://engemannshc.usc.edu/rsvp/

Sexual Assault Resource Center: For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: http://sarc.usc.edu/

Office of Equity and Diversity (OED)/Title IX compliance – (213) 740-5086: Works with faculty, staff, visitors, applicants, and students around issues of protected class. https://equity.usc.edu/

Bias Assessment Response and Support: Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. https://studentaffairs.usc.edu/bias-assessment-response-support/

The Office of Disability Services and Programs: Provides certification for students with disabilities and helps arrange relevant accommodations. Dsp.usc.edu

USC Support & Advocacy – (213) 821-4710: Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. https://studentaffairs.usc.edu/ssa/

Diversity at USC – https://diversity.usc.edu/: Tabs for Events, Programs and Training, Task Force (including representatives for each school), Chronology, Participate, Resources for Students

USC Emergency Information: Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. emergency.usc.edu

USC Department of Public Safety – UPC: (213) 740-4321 – HSC: (323) 442-1000 – 24-hour emergency or to report a crime: Provides overall safety to USC community. Dps.usc.edu

Students with Disabilities USC is committed to making reasonable accommodations to assist individuals with disabilities in reaching their academic potential. If you have a disability which may impact your performance, attendance, or grades in this course and require accommodations, you must first register with the Office of Disability Services and Programs (www.usc.edu/disability). DSP provides certification for students with disabilities and helps arrange the relevant accommodations. Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to your TA) as early in the semester as possible. DSP is located in GFS (Grace Ford Salvatori Hall) 120 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776. Email: ability@usc.edu.