Revenue Optimization and Marketplace Design

ORIE 4154: Syllabus

Spring 2017

Essential Course information:

Lectures and Recitations
Class time: TR 11:40am-12:55pm
Class location: Thurston 205
Website: http://people.orie.cornell.edu/sbanerjee/ORIE4154/orie4154s17.html
Piazza page: http://piazza.com/cornell/spring2017/orie4154

Instructor
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Office hours: Tuesday 3pm-5pm (or by appointment)

Teaching Assistants
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Office hours: Monday, Wednesday 3-5pm Room no: TBD

Course description:

This course aims to expose students to modeling and optimization techniques which can be used to design a company's *interface with the market*. In particular, this can take two forms:

- *Demand management* – determining how to sell "*the right product to the right customer at the right time for the right price*"
- *Marketplace design* – determining "*who gets what and why (and at what price)*" in two-sided platform marketplaces.

We will draw on a rich body of research spanning three disciplines – operations management, economics and computer science – and study a collection of related (yet diverse) mathematical models and techniques. The models we cover have proved successful in practice across various industries; however, given the transformations brought about by the advent of online commerce and increased use of smartphones, our aim is to provide students with tools that generalize to new domains.

Topics and learning outcomes

We will cover a variety of topics, spanning across demand management and marketplace design, so as to get a sense of the main ideas in each field. In particular, the course will comprise of five modules:

1. **Demand Management via Allocation/Pricing Decisions**: Capacity allocation and protection levels for a single leg with single and multiple fare classes (Littlewood's model); overbooking; network revenue management; dynamic pricing; approximation techniques.
2. **Probabilistic Choice**: Customer choice models; Luce's axioms and MNL; assortment optimization.
3. **Joint demand estimation and management**: dynamic pricing with demand learning; the multi-armed bandit paradigm.
4. **Mechanism design and auctions**: VCG mechanism; Myerson's optimal auction; simple auctions.
5. **Pricing in two-sided marketplaces**: Models of two-sided markets; insulating prices.

This course aims to provide students with three learning outcomes:

1. Exposure to RM and marketplace models: Our primary goal is to learn how to model pricing and market design problems in various settings; students will learn a variety of existing models, with applications in transportation, retail, hospitality and the sharing economy.
2. Fundamental methodologies: The course will also expose students to several fundamental OR methodologies; in particular, we will cover:
   - (stochastic) dynamic programming
   - approximation techniques for DPs
   - choice modeling
   - bandit paradigms
   - mechanism design and auctions
   - price theory of two-sided marketplaces
3. Research Problems: This is an exciting time for pricing problems, with new applications and e-commerce platforms driving a host of new research directions, and providing data and testbeds for validation. The course will expose students to these developments, and help them do independent research.

Prerequisites:

Students should be comfortable with basic probability and optimization (at the level of **ORIE 3500** and **ORIE 3300**, or equivalent); in particular, I will expect familiarity with random variables; conditional probability and expectation; common probability distributions and their properties (binomial, geometric, exponential, Poisson, Gaussian); linear programming and duality; basic combinatorial optimization. Prior exposure to stochastic processes, algorithm design and game theory would be very helpful, but is not necessary.

The assignments will also involve some coding: our preference is that students use **Python** for these problems, and submit iPython notebooks with annotated code and plots.

Send me a mail if you are concerned about having the appropriate prerequisites and/or prefer to use an alternate language for programing assignments.

Course communication

We will post course materials on the course website, and use Blackboard for announcements (if registered, you should be enrolled; if not, visit `https://blackboard.cornell.edu/` and search for ORIE 6180). All announcements for the class will be through Blackboard, so it is your responsibility to ensure that you are enrolled and receiving the announcements. Please contact the instructor or the TA if you have any issues.

We will also use Piazza as an online discussion forum for all course-related questions. This is the most effective way to communicate with course staff; please avoid email if Piazza will do. You are encouraged to post any questions you might have about the course material. The course staff will monitor Piazza closely and you will usually get a quick response. If you know the answer to a question, you are encouraged to post it. By default, your posts are visible to the course staff and other students; however, you can post privately so that only the course staff can see your question, and should do so if your post might reveal information about a solution to a homework problem. You can also post anonymously if you wish. If you post privately, we reserve the right to make your question public if we think the class will benefit. Everyone who preregistered for the course should already be signed up. If you have never used Piazza before, or if you did not preregister for the course, visit the Piazza ORIE 4154 page to sign up.

Grading:

The grade will be based on assignments ($\sim$45%), one prelim exam ($\sim$20%), a final exam ($\sim$30%) and class participation ($\sim$5%); as the course proceeds, we may make small adjustments to these weights if required. In addition, students can choose to do an optional project (see below).

Homework policy

Typesetting and submission: *All assignment solutions must be submitted online* – in particular, we will use CMS for assignment submissions (instructions in first homework). We encourage all students to *typeset* their solutions, with scans of hand-drawn figures if required. Most homework assignments will be due on Friday at 11:59pm.

Late submissions and drops: You have *six late days*; late submission will be graded only if you use your late days. You can use at most three late days per homework. If you are unable to submit your homework because of extenuating circumstances (medical or family emergency), contact an instructor beforehand.

Students *must submit all assignments* – at the least, you should submit a blank sheet with your name. For students who submit all assignments, *we will drop the lowest homework grade.*

Collaboration: You can collaborate with other students in the course and exchange ideas about homework – in fact, we would encourage students to attempt the assignments in groups of $3-4$. However, you are not allowed to share written notes about homework in any form, and need to write up your homework submission completely on your own. *Your submission has to acknowledge all students that you collaborated with on the homework.* Failure to acknowledge collaborators is a violation of academic integrity.

Project

In addition to the above, interested students have the option of doing an *optional* research project, ideally in groups of 2-3. The project grade can be used to replace 3 assignment grades (after

dropping lowest), OR the prelim grade. In addition, *the A+ grade will be reserved for students doing a project.*

Students interested in a project should speak to the instructor before spring break, and *must submit a 1 page proposal on* **Tuesday, April 11, 2017** (right after spring break). The final project report will be during the finals.

Resources:

There is no required textbook for the class. We will cover materials from a variety of sources, and relevant notes and references will be uploaded on the website – students are responsible for topics covered in lecture and any assigned readings. That said, there are several books which provide an excellent treatment of the topics we will cover:

- Big picture overviews:
  - Pricing and Revenue Optimization by Robert Phillips
  - Principles of Pricing by Vohra and Krishnamurthi

  Both these books provide insight into the history and organizing principles of pricing and revenue optimization – the former from an operations viewpoint, and the latter from an economics and marketing perspective. They are highly recommended to give students a sense of the breadth of topics in pricing.
- For revenue management:
  - The Theory and Practice of Revenue Management by Talluri and van Ryzin

  This excellent, though somewhat techncial book collects most of the main revenue management results, as well as a nice summary of the applications of RM in various industries.
- For mechanism design: I will adopt an algorithmic viewpoint, based closely on the following:
  - Twenty Lectures on Algorithmic Game Theory by Tim Roughgarden – We will cover material based on the first 8 lectures (you can also refer to Tim's original lecture notes at `http://theory.stanford.edu/~tim/notes.html`.)
  - Mechanism Design and Approximation by Jason Hartline – available online; more technical and detailed coverage of the same topics.

Academic integrity:

You are expected to abide by the Cornell University Code of Academic Integrity. Any work submitted by you in this course for academic credit should be your own. The complete code is available at `http://cuinfo.cornell.edu/Academic/AIC.html`.