STOCHASTIC PROGRAMMING - DNSC 8394

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School of Business – The George Washington University

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Office Hours: On appointment

Class: Monday, 4:00PM-6:30PM

Place: Duques 357

PREREQUISITE

This course is suitable for students with some knowledge in optimization and probability.

OVERVIEW

This course will focus on Stochastic Modeling and Programming. Stochastic Programming is a discipline intersecting with probability theory and statistics on one hand and with mathematical programming on the other hand. It is a framework for modeling optimization problems that involve uncertainty. While deterministic optimization problems are formulated with known parameters, real world problems almost invariably include some unknown ones; their eventual outcome depends on the future realization of random events.

Stochastic Programming relies upon the fact that probability distributions governing the data are known or can be estimated. The goal here is to find some policy that is feasible for (almost) all possible realizations and optimizes a function of the decision and the random variables. More generally, such models are formulated, analytically or numerically solved, and studied in order to provide useful information to the decision-maker.

Over the semester, students attend a weekly 2 hour-and-half lecture and should be prepared to devote a minimum of ten hours of self-study per week (this minimum expectation will more than double in some weeks), in addition to the weekly class.

OBJECTIVES

The main objectives of this course are to:

- Develop the capacity to model stochastic systems and decision processes and to formulate the corresponding optimization programs.
- Learn the concepts and the basic theory of the stochastic programming discipline.
- Understand the structure of stochastic models and programs.
- Get acquainted with algorithmic techniques used in stochastic programming.
- Learn stochastic computational tools, solvers and algebraic modeling languages. The AMPL modeling language will be extensively used to model and solve different types of stochastic optimization problems.
- Incorporate stochastic modeling and programming into your research.

COURSE MATERIAL

Copies of papers and chapters of textbooks will be distributed. Suggested references are:

- Birge J.R., Louveaux F. 2011. *Introduction to Stochastic Programming.* Springer-Verlag. Second Edition.

  The first edition of this book is available online at the Gelman library.

- Kall P., Mayer J. 2005. *Stochastic Linear Programming: Models, Theory, and Computation*. Springer.

- Prékopa A. 1995. *Stochastic Programming*. Kluwer. Boston, MA.

- Ruszczyński A. and Shapiro A. 2003. Stochastic Programming: Handbook in Operations Research and Management Science **10**. Elsevier.

- Fourer R., Gay D.M., Kernighan B.W. 2002. *AMPL: A Modeling Language for Mathematical Programming*. Duxbury Press / Brooks / Cole Publishing Company.

GRADING

The course grade is a weighted average of three components:

- 20% Participation.
- 30% Homework: Three to four homework assignments will be given. You should start working on each homework early so that you will have time to ask questions in class before the homework is due. You are encouraged to discuss homework and learn from each other, but each person must submit her/his own work. Late homework will not be accepted and no make-up homework assignment will be given. A grade received in any exam or homework becomes permanent one week after it is returned.
- 50% Exam or Research Project. To substitute a research project to the final exam, the student must submit a proposal by February 5th and receive the approval of the instructor.

  Research project: If interested in a project, you are expected to start looking for a suitable topic and project **as soon as possible**. The hope is that many of these term projects will lead to conference presentations, theses or publishable papers. The milestones for the project are:

  i) Project choice, approval and outline: Students are expected to submit a written description (3-4 pages) of the project and give a short presentation on a date to be specified (in February). The description will encompass the following points:

  1. Description of the problem.
  2. Formulation of the problem.
  3. Reasons why the problem is a good project topic. Computationally hard to solve (structure of the problem, preliminary results, etc.), not much work has been done on it, etc.
  4. Solution method (appropriateness, coding or modeling language) that will be used in the project.
  5. Outline of the tasks and expected completion times.

ii) Written project report: The due date is April 21. The project report is an extension of the project proposal and is expected to contain the following sections:

1. Introduction: scope, objectives and contribution.
2. Problem definition and formulation, and succinct review of the relevant literature.
3. Discuss the solution method used and why you have chosen it. If the solution methods require reformulating the problem, write down the reformulations. If there are different possible reformulations, discuss the advantages and disadvantages of each.
4. Give details of the design of your experiments before discussing the computational results.
5. Precise presentation of computational results (solution times, proven optimality or not, bounds, optimality gaps) and discussion of the empirical observations and conclusions. Relate them to your initial expectations.
6. Make sure that your programs are well-commented. Attach your computer programs as an appendix to your report. Send me your program, a small data set for testing and instructions on how to run them as an email attachment.

iii) Oral project presentation: Plan for a 15-min presentation and a 5-min discussion per project. The purpose of the presentations is to learn from each other's experiences and give/receive feedback.

TENTATIVE SCHEDULE

The list of topics is tentative and is subject to update:

- Lecture 1: Introduction to Stochastic Programming.
- Lecture 2:
  - Value of Perfect Information and Stochastic Solution.
  - Modeling with AMPL: basics.
- Lecture 3:
  - Probabilistic Programming: Static Stochastic Programming Problems.
  - Lecture 3: Log-Concavity Theory.
- Lecture 4: Numerical Solution Methods for Probabilistic Problems.
- Lecture 5: Boolean Modeling Framework for Probabilistically Constrained Problems.
- Lecture 6: Bounding Schemes and Relaxations.
- Lectures 7-8:
  - Distributionally Robust Optimization.
- Lectures 9-10:
  - Stochastic Programming with Recourse: Two-Stage Programming.
  - L-Shaped Decomposition Method.
- Lecture 11:
  - Multi-Stage Programming.
  - Stochastic Dual Dynamic Programming.
- Lecture 12:
  - Risk-Averse Optimization with Stochastic Dominance Constraints.
  - Sample Approximation Method.
- Lecture 13: Risk Metrics and Stochastic Formulations: Financial Applications.
- Lecture 14: Projects' presentations.

ASSIGNMENT OF CREDIT HOUR POLICY

Students will spend 2.5 hours per week in class. Out of class, they will spend an average (per week) of 12 hours for readings, homework and computational assignments, and projects. Over the course of the semester, students will spend 35 hours in in instructional time and 168 hours preparing for class. Instructional time includes discussions and activities in class.

ACADEMIC INTEGRITY

The code of academic integrity applies to all courses in the George Washington School of Business. Please become familiar with the code. All students are expected to maintain the highest level of academic integrity throughout the course of the semester. Please note that acts of academic dishonesty during the course will be prosecuted and harsh penalties may be sought for such acts. Students are responsible for knowing what acts constitute academic dishonesty.

The code may be found at: http://www.gwu.edu/~ntegrity/code.html.

Special Considerations:

If a student has a special need, University policy states that the student must co-ordinate with the Office for Disability Services and present the course instructor with the appropriate documentation detailing the fair accommodations for the student. This policy is intended to ensure fairness for all students and privacy for the student with special needs. If you have a special need, please do not wait until after an exam or assignment to present the instructor with evidence of your need as consideration may not be given retroactively. The instructor ensures your privacy will be protected when accommodating special needs.

The University administration has accepted a resolution of the Faculty Senate regarding accommodations of religiously observant students and faculty. The requirements of this resolution state that students must notify faculty during the first week of the semester of their intention to be absent from class on their day(s) of religious observance. Faculty member will extend to these students the courtesy of absence without penalty on such occasions, including permission to make up examinations.