Optimization under uncertainty: modeling and solution methods

A Ph.D. level course given within the framework of the Ph.D. program in *Applied Mathematics*

LECTURER

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AIM

The aim of the course (30 lecture house) is to strengthen the knowledge of optimization methods, extending modeling and solution procedures to cases affected by significant uncertainty. Uncertainty is pervasive in many branches of engineering and social sciences, including finance, supply chain management, energy markets, and telecommunication networks. Emphasis is on stochastic programming models, but, since a stochastic characterization of uncertainty is not always available, reliable, or appropriate, we will also consider robust optimization frameworks. Furthermore, since solving multistage stochastic optimization models is quite challenging, we will also deal with Approximate Dynamic Programming methods that, among other things, illustrate the connection between mathematical optimization and machine learning. Case studies and examples are used throughout the course to illustrate the relevance of its content.

Prerequisites: some familiarity with standard linear programming models; essentials of probability theory; programming languages, as well as working knowledge of MATLAB or R. We will also use AMPL (www.ampl.com) to build and solve optimization models (a free, time-limited license will be provided).

CONTENT

- Introductory examples and motivations; the impact of uncertainty; expected value of perfect information and value of the stochastic solution.
- Alternative paradigms: stochastic programming with recourse; chance-constrained optimization; robust optimization.
- A refresher on optimization theory: convexity; duality; solution methods for linear, nonlinear, and mixed-integer programming models.
- Decomposition methods for stochastic programming models with recourse.
- Solution methods for mixed-integer stochastic optimization models.
- The formulation of dynamic optimization models under uncertainty.
- Scenario generation: Monte Carlo; deterministic methods (quasi-Monte Carlo, Gaussian quadrature, moment matching).
- Risk measurement and management: utility functions; coherent risk measures.
- Simulation-based optimization.
- Dynamic programming: Bellman's equation; learning the value function by Monte Carlo simulation and linear regression.
- Robust optimization: nonstochastic representation of uncertainty; solution methods based on convex optimization.

References

- P. Brandimarte. Quantitative Methods: An Introduction for Business Management. Wiley 2011.
- P. Brandimarte. Handbook in Monte Carlo Methods: Applications in Financial Engineering, Risk Management, and Economics. Wiley 2014.
- A.J. King, S.W. Wallace. Modeling with Stochastic Programming. Springer, 2012.

- W.B. Powell. Approximate Dynamic Programming: Solving the Curses of Dimensionality (2nd ed.). Wiley, 2011.
- A. Ben-Tal, L.. El Ghaoui, A, Nemirovski. Robust Optimization. Princeton University Press, 2009.
- S.W. Wallace, W.T. Ziemba (eds.). Applications of Stochastic Programming. SIAM, 2005.

ASSESSMENT
In order to formally record the associated credits, **individual** homework will be assigned during the course, with firm deadlines along the way. You are required to write MATLAB (or R) code, as well as AMPL scripts.

SCHEDULE
Lectures will be given at Dipartimento di Scienze Matematiche (DISMA), Politecnico di Torino, in Aula Buzano (the internal lecture/seminar room of DISMA, third floor).

Lecture	Date	Time
1	Monday, March 27th	10:00 - 13:00
2	Friday, March 31st	10:00 - 13:00
3	Monday, April 3rd	10:00 - 13:00
4	Friday, April 7th	10:00 - 13:00
5	Monday, April 10th	10:00 - 13:00
6	Friday, April 21st	10:00 - 13:00
7	Monday, April 24th	10:00 - 13:00
8	Friday, April 28th	10:00 - 13:00
9	Friday, May 5th	10:00 - 13:00
10	Monday, May 8th	10:00 - 13:00