Ph.D. School in
Analytics for Economics and Business

COURSE: Stochastic Optimization

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Course description and objectives

The course carries 4CFU and it is structured in four parts dedicated to a) two-stage stochastic programs, b) multi-stage stochastic programs, c) scenario generation and d) solution methods for stochastic programs. The course will enable doctoral students to get in-depth theoretical and practical knowledge of optimization problems involving uncertain parameters for which stochastic models are available. Optimization problems involving stochastic models occur in almost all areas of science and engineering, from transportation, energy to finance [6-9]. Due to the presence of uncertainty, the theory combines concepts of the optimization, probability, statistics and functional analysis.

The first two parts of the course address modeling issues and theory of both two-stage and multistage stochastic programs. Stochastic programming examples from different applications areas, which intend to help the student build intuition on how to model uncertainty, are presented. The basic concepts such as recourse actions, chance (probabilistic) constraints, the non-anticipativity principle, the scenario tree and the value of information are introduced in the context of specific models such as the farmer problem or the news vendor problems [1-4]. In a more general setting, conditions for optimality, solution stability, the forms of the feasible region and objective function will be also addressed.

Part three and four of the course address several methods for scenario generation from crude Monte Carlo sampling, moment matching, optimal discretization to scenario reduction and solution methods for stochastic programming [10-15].

Exposure to foundation, seminal contributions as well as to current results and software developments will enable the students to link in a consistent and rigorous way state-of-the-art theory and practical approaches in this area.

Outline

a) Two-stage stochastic programs
   - a.1 definition
   - a.2 primal and dual problems
   - a.3 key results
   - a.4 probability space and maxmin approach

b) Multi-stage stochastic programs
   - b.1 dynamic (multistage) stochastic optimization
   - b.2 nonlinear stochastic programs
   - b.3 value of information

b.4 time consistency
b.5 stochastic control and dynamic stochastic programming
Lab session – Matlab+Gams

c) Scenario generation
c.1 methods for scenario generation
c.2 crude Monte Carlo
c.3 distances between probability spaces
c.4 importance sampling – expected value of perfect information
c.5 scenario reduction
Lab session – scenario reduction

d) Solution methods for stochastic programs
d.1 direct methods
d.2 decomposition methods
d.3 approximate methods
Lab session – GAMS solvers

References

1. John R.Birge, Francois Louveaux: *Introduction to stochastic programming*. 2nd edition Springer 2011
2. Marida Bertocchi, Giorgio Consigli and Michael A.H.Dempster eds: *Stochastic optimization methods in finance and energy*. Fred Hillier series on Management science and Operations research, Springer 2011
3. Jozsef Abaffy, E.Allevi, M.Bertocchi e V.Moriggia: *Programmazione stocastica e applicazioni*. Egea Pbl 2010
4. **http://stoprog.org/** website of the community of Stochastic Programming.
5. P. Kall, S. W. Wallace, Stochastic Programming, Wiley-Interscience Series in Systems and Optimization, Wiley, Chichester, 1994.
6. Maggioni, F., Vespucci, M.T., Allevi, E., Bertocchi, M.I. & Innorta, M. (2008) A two-stage stochastic optimization model for a gas sale retailer. *Kybernetika*, **44**(2), 277–29
7. F.Maggioni, M. Kaut, L. Bertazzi, (2009) Stochastic optimization models for a single-sink transportation problem, *Comput. Manag. Sci.,* **6**(2), 251-267.
8. Maggioni, F., Allevi, E., Bertocchi, M.I. & Potra, F. (2009) Stochastic Second-order cone programming in mobile ad hoc networks. *J. Optim. Theory Appl.*, **143**, 309–328
9. F. Maggioni, M. T. Vespucci, E. Allevi, M. Bertocchi, R. Giacometti & Innorta, M. (2010) A stochastic optimization model for gas retail with temperature scenarios and oil prices parameters, *IMA Journal of Management Mathematics*, **21**, 149-163.
10. Maggioni, F. & Wallace, S.W. (2012) Analyzing the quality of the expected value solution in stochastic programming. *Annals of Operations Research*, **200**(1), 37–54.
11. Maggioni, F., Allevi, E. & Bertocchi, M. (2013) Bounds in Multistage Linear Stochastic Programming. *J. Optim. Theory Appl.* DOI 10.1007/s10957-013-0450-1
12. Maggioni, F. & Pflug, G. (2016) Bounds and approximations for multistage stochastic programs, Siam Journal on Optimization, 26(1), 831–855.
13. Maggioni, F., Allevi, E. & Bertocchi, M. (2016) Monotonic bounds in multistage mixed-integer linear stochastic programming, Computational Management Science, 13(3), 423-457

14. Extended set of articles and references distributed in class.
15. Lecture notes.