ID de Contribution: **61**

Type: **Contributed talk**

Solving Two-Stage Programs with Endogenous Uncertainty via Random Variable Transformation

mardi 29 juillet 2025 10:45 (24 minutes)

Real-world decision-making problems often involve decision-dependent uncertainty, where the probability distribution of the random vector depends on the model's decisions. Few studies focus on two-stage stochastic programs with this type of endogenous uncertainty, and those that do lack general methodologies. We propose a general method for solving a class of these programs based on random variable transformation, a technique widely employed in probability and statistics. The random variable transformation converts a stochastic program with endogenous uncertainty (original program) into an equivalent stochastic program with decision-independent uncertainty (transformed program), for which solution procedures are well-studied. Additionally, endogenous uncertainty usually leads to nonlinear nonconvex programs, which are theoretically intractable. Nonetheless, we show that, for some classical endogenous distributions, the proposed method yields mixed-integer linear or convex programs with exogenous uncertainty. We validate this method by applying it to a network design and facility-protection problem, considering distinct decision-dependent distributions for the random variables. While the original formulation of this problem is nonlinear nonconvex for most endogenous distributions, the proposed method transforms it into mixed-integer linear programs with exogenous uncertainty. We solve these transformed programs with the sample average approximation method. We highlight the superior performance of our approach compared to solving the original program in the case a mixed-integer linear formulation of this program exists.

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Classification de Session: Mini-symposium

Classification de thématique: Stochastic Programming