MATHEMATICAL SCIENCES

DISMA/CRT - Applied robust and stochastic optimization

Funded By	Dipartimento DISMA FONDAZIONE CRT CASSA DI RISPARMIO DI TORINO [P.iva/CF:06655250014]

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Context of the research activity	Practical problems in managerial domains like production scheduling, vehicle routing, supply chain management, financial markets, or quantitative marketing are subject to considerable uncertainty. Optimization models to support decision making must be able to tackle uncertainty in risk factors like demand, machine breakdowns, market return and volatility, consumer’s response to price and quality. Stochastic programming and robust optimization provide us with the necessary basic tools. The research program aims at the development of models and solutions methods in these domains.

Objectives	The research program aims at the development of optimization models in selected application areas, the implementation of computational solution methods, and the experimental analysis of performance in terms of computational efficiency, as well as solution quality and robustness. Applications areas will be selected, depending on the candidate background and the possible interactions with the industry. They include: • Machine scheduling, warehousing, and vehicle routing • Production planning problems under demand uncertainty. • Network design and capacity planning for inventory and transportation. • Assortment models in retail and optimal pricing. • Risk management in energy markets. • Robust machine learning models. • Use of surrogate models in multiobjective and robust engineering design. • Portfolio management and hedging of derivative securities in incomplete markets. The solution methods include stochastic programming with recourse, approximate dynamic programming and reinforcement learning, classical worst-case robust optimization, distributionally robust optimization, and metamodeling for optimizing expensive functions. In order to successfully apply these tools to a practical problem, we must: • Characterize uncertainty in terms of underlying risk factors and their mapping to a performance measure of interest.

	• Devise appropriate solution strategies, able to deal with the curse of the dimensionality and other computational challenges. • To check performance on a suitable testbed, by generating a range of test problems, on which algorithms may be checked, not only in terms of the tradeoff between solution quality and computational effort, but also in terms of robustness to problem misspecification. Indeed, one of the key difficulties that we have to face is the possible lack of data, which may prevent us from building a reliable stochastic model of uncertainty. Hence, we have to deal with data-driven approaches, optimal learning, and optimization under distributional ambiguity. Hence, the research program comprises the following steps: 1. Acquiring the necessary theoretical background in optimization under uncertainty (integer programming and combinatorial optimization, convex analysis, duality in optimization, scenario generation, decomposition methods, learning strategies, etc.). 2. Selecting the application fields and strengthening the specific domain knowledge. 3. Implementation of the solution strategies. 4. Definition of the testbed (possibly, in cooperation with the industry). 5. Computational experiments.

Skills and competencies for the development of the activity	The research program requires hybrid competences and is not well suited to either pure mathematicians or engineers without a strong quantitative background: • Strong background in computational optimization and operations research, with emphasis on combinatorial optimization, convex optimization, and optimization under uncertainty (stochastic programming, dynamic programming, worst-case robust optimization). • Adequate practical knowledge in at least two of the following domains: scheduling and routing; supply chain management; retailing/marketing and choice models; operations management (production planning, inventory control, service science; energy markets; simulation-based optimization in engineering design); computational finance and risk management. • Strong background in probability and statistics (including the ability to devise an experimental plan and to critically analyze the computational results). • Programming skills in Python/MATLAB.