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Learning-based Robust Optimization: Procedures and Statistical Guarantees

L. Jeff Hong

Department of Management Science, City University of Hong Kong, 86 Tat Chee Ave., jeffhong@cityu.edu.hk

Zhiyuan Huang

Department of Industrial and Operations Engineering, University of Michigan, 1205 Beal Ave., Ann Arbor, MI 48109, zhyang@umich.edu

Henry Lam

Department of Industrial and Operations Engineering, University of Michigan, 1205 Beal Ave., Ann Arbor, MI 48109, khlam@umich.edu

Robust optimization (RO) is a common approach to tractably obtain safeguarding solutions for optimization problems with uncertain constraints. In this paper, we study a statistical framework to integrate data into RO, based on learning a prediction set using (combinations of) geometric shapes that are compatible with established RO tools, and a simple data-splitting validation step that achieves finite-sample nonparametric statistical guarantees on feasibility. Compared with previous data-driven approaches, our required sample size to achieve feasibility at a given confidence level is independent of the dimensions of both the decision space and the probability space governing the stochasticity. Our framework also provides a platform to integrate machine learning tools to learn tractable uncertainty sets for convoluted and high-dimensional data, and a machinery to incorporate optimality belief into uncertainty sets, both aimed at improving the objective performance of the resulting RO while maintaining the dimension-free statistical feasibility guarantees.

Key words: robust optimization, chance constraint, prediction set learning, quantile estimation

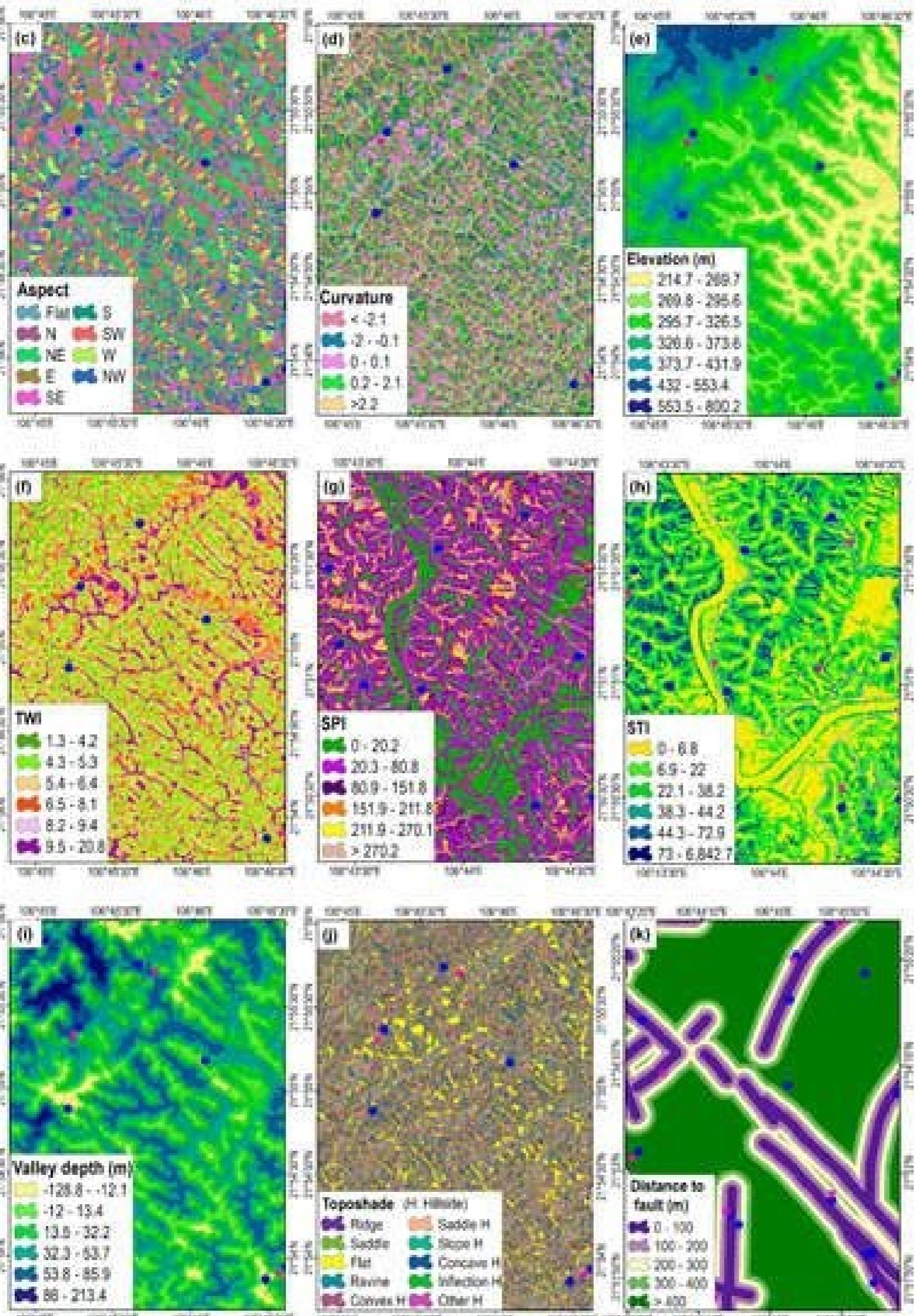
History:

1. Introduction

Many optimization problems in industrial applications contain uncertain parameters in constraints where the enforcement of feasibility is of importance. Coupled with the complexity growth and the proliferation of data in modern applications, these problems increasingly arise in large-scale and data-driven environments. This paper aims to build procedures to find good-quality solutions for these uncertain optimization problems that are tractable and statistically accurate for high-dimensional or limited data situations.

To locate our scope of study, we consider situations where the uncertainty in the constraints is “stochastic”, and a risk-averse modeler wants the solution to be feasible “most of the time” while not making the decision space overly conservative. One common framework to define feasibility in this context is via a chance-constrained program (CCP)

$$\text{minimize } f(x) \text{ subject to } P(g(x; \xi) \in \mathcal{A}) \geq 1 - \epsilon \quad (1)$$



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