THE UNIVERSITY OF CHICAGO | DEPARTMENT OF STATISTICS

Master's Thesis Presentation

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"Asymptotically Optimal Conformal Prediction for Classification"

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Abstract

Conformal prediction provides distribution-free marginal coverage guarantees and can be combined with arbitrary machine learning prediction algorithms. This thesis adopts a model-based perspective on conformal prediction for classification, aiming to obtain guarantees stronger than marginal validity, including asymptotically minimized set length and conditional validity, by incorporating model information into the design of the score function. The thesis consists of two parts. First, we formalize randomized oracles in the standard multiclass classification setting using a generalized Neyman-Pearson lemma and investigate their advantages over the deterministic oracle induced by discreteness. Among all feasible randomized oracles, we identify one that yields low variance in prediction-set length and develop a framework for establishing the asymptotic optimality of the corresponding randomized conformal prediction procedure. This framework relaxes the usual no-ties assumption and other regularity conditions commonly imposed in standard analyses of model-based conformal prediction. Second, we study asymptotically optimal conformal prediction for ordinal classification, where an additional structural contiguity constraint is required. Within the nested conformal framework, we construct a score function that produces contiguous prediction sets while accommodating arbitrary nonparametric estimators of the conditional distribution. We then prove the asymptotic optimality of the resulting conformal prediction procedure under a unimodality assumption. Numerical experiments on real data demonstrate improved performance relative to existing alternatives.

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