

SEMINAR

Grupo de Análise Funcional e Aplicações Functional Analysis and Applications Group

Enhancing conformal prediction efficiency via multiscale impurity analysis: a complexity-aware non-conformity function

Diogo Costa
Universidade de Aveiro

Abstract

Conformal Prediction (CP) has emerged as a robust paradigm for trustworthy machine learning, offering mathematically guaranteed marginal error bounds. However, its practical utility is often constricted by predictive efficiency. Standard non-conformity functions typically treat data instances uniformly, neglecting the localized complexity of decision boundaries and resulting in prediction regions that fail to adapt to underlying data heteroscedasticity. To address this validity-efficiency trade-off, this study introduces the integration of the Multiscale Impurity Analysis (MIA) algorithm into the Inductive Conformal Prediction framework. This novel, model-agnostic approach dynamically scales non-conformity scores by weighing prediction uncertainty against local data separability. For classification tasks, MIA utilizes generic entropic measures to adjust prediction sets, while for regression, it employs localized variance analysis to adapt interval widths. Additionally, a Unified Conformal Evaluation Metric (UCEM) is proposed to holistically evaluate classification efficiency by balancing set inclusion, exclusivity, and empty-set abstentions. Extensive experimental validation demonstrates that the MIA-enhanced CP method significantly improves predictive efficiency, yielding smaller prediction sets and tighter intervals, while maintaining valid marginal coverage.

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