Dissertation Defense

From Uncertainty Aware to Decision Ready: Specialized UQ Methods for High-Stakes Predictive Modeling

Shifan Zhao

Abstract: Uncertainty quantification (UQ) is essential for reliable decision-making in predictive modeling, particularly those with high-stakes outcomes. This thesis develops a unified framework that tailors uncertainty quantification methods to AI foundation models with distinct application domains. For stationary foundation models, we enhance traditional Gaussian Process regression—through kernel preconditioning and a two-stage modeling approach—to address computational inefficiencies, approximation bias, and model misspecification, thereby improving uncertainty estimates. For nonstationary foundation models, we integrate conformal prediction techniques to exploit theoretical guarantees of data coverage. We apply our methods to medical and climate foundations models, and numerical experiments demonstrate that our targeted approaches produce reliable and actionable estimates of uncertainty. This work shows the potential to substantially advance the state of predictive modeling for both healthcare and extreme weather applications.

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Advisor: Talea Mayo

Mathematics
Emory University