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Generalized Hoeffding decomposition and the linear nature of non-linearities

Hoeffding's functional decomposition plays a crucial role in global sensitivity analysis and explainable AI, enabling the extraction of meaningful insights from black-box models. However, its application traditionally relies on the assumption of mutual independence among the model's inputs. Generalizing this result to non-mutually independent inputs has been an important challenge in the field of uncertainty quantification. In this talk, we will explore how this decomposition can be extended to accommodate dependent inputs, given two reasonable assumptions: non-perfect functional dependence and non-degenerate stochastic dependence. This generalization requires approaching the problem using a framework at the cornerstone of probability theory, functional analysis, and combinatorics. This generalization can be approached as a direct-sum decomposition problem of generated Lebesgue space, unveiling a surprisingly linear approach to handling stochastic and functional non-linearities. The proposed "ortho-canonical decomposition" relies on oblique projections rather than the traditional conditional expectations.