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Overcoming challenges in sensitivity analysis for complex models in nuclear and renewable energy applications

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Our presentation will focus on the critical challenges and advancements in sensitivity analysis for complex models used in nuclear and renewable energy applications.

Firstly, we will discuss the intricacies of sensitivity analysis for models involving dependent variables, time series, and multiphysics couplings, each requiring the adaptation of standard methodologies. When dealing with dependent inputs, the challenge is to strike a balance between interpretability, effective screening performance and constrained inference. Current trends, such as Johnson's relative weights, Shapley values and dependence measures based on Hilbert-Schmidt independence criterion (HSIC), do not fully meet engineers' expectations. Moreover, the treatment of time series, where the data come from a single time series, raises theoretical questions about the probabilistic guarantees of the usual methods (confidence intervals for Sobol indices or p-values for HSIC indices). In addition, multiphysics simulation, where several sub-models sharing state variables are interconnected, presents the challenge of how to use sensitivity analyses of each sub-model to reconstruct an overall analysis of the system.

Secondly, we will address how sensitivity analysis integrates into the robust optimization under constraints framework, especially when dealing with a large number of inputs, including uncertain ones.

Thirdly, we will explore the role that sensitivity analysis can play in enhancing the explicability of machine learning (ML) models, thereby serving their intelligibility and auditability. The extensive use of ML models in data-driven AI systems, particularly those subject to new European regulations, requires a deep understanding of the decisions and results provided by these models. This notably involves comprehending the influence of input features on predicted variables and providing global interpretability diagnostics. Strong connections between Explainable AI (XAI) and global sensitivity analysis have been recently highlighted, and constitute an appealing research perspective.

Finally, some software developed by our companies will be presented, and the issues addressed will be illustrated by application cases from our respective sectors (reactor performance analysis, accident transient monitoring, fuel behavior simulation and seismic analysis).

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