MSc thesis proposal with international collaboration

(in collaboration with Massachusetts Institute of Technology)

❖ Title of the research

Inverse Uncertainty Quantification with Deep Learning Surrogate Models of Accident Scenarios in Nuclear Microreactors

❖ Objectives of the research

Future-generation nuclear reactors are characterized by novel designs that remain largely untested and lack failure data and past information. Their licensing requires extensive development of multi-physics Best Estimate (BE) modeling and simulation (M&S) to be integrated with experiments in order to investigate possible accidental scenarios. BE models consider the uncertainty in the input parameters, which is associated with the randomness and ignorance of the exact value of design variables and calibration parameters, and provide estimates with measures of confidence for the simulation outputs. The BE models are computationally expensive and require the use of Deep Learning (DL) and Machine Learning (ML) to develop surrogate models to speed up the simulations when investigating complex scenarios. Such DL and ML models can be used to perform uncertainty quantification, sensitivity analyses and to predict the response of the nuclear reactor during accident scenarios (Abdar et al., 2021).

Inverse UQ assesses and updates the model input parameter uncertainties based on experimental data (Xie et al., 2021). This allows considering the actual state of the nuclear reactor in the simulation model, calibrating design variables and reducing the uncertainty of the outputs. The goal of the thesis is to develop an approach for inverse UQ using deep-learning surrogate models. The approach will be validated on a simulation model of a nuclear battery, which is a transportable, plug-and-play, heat-pipe-cooled microreactor (Buongiorno et al., 2021). The considered nuclear battery is a semi-autonomous 5 MW (thermal) high-temperature heat-pipe-cooled yttrium-hydride moderated microreactor designed at MIT (Antonello et al., 2022).

The thesis project consists in the following steps:

- Literature review, especially on *i*) microreactors and nuclear batteries design, ii) inverse uncertainty quantification, and iii) deep learning-based surrogate models.
- Getting acquainted with the modeling and simulation tool of the NB and the developed surrogate models.
- Methodology development.
- Implementation of the algorithms in Python (and Matlab).
- Application and validation of the methodology.

References

Antonello, F., Buongiorno, J., & Zio, E. (2022). A methodology to perform dynamic risk assessment using system theory and modeling and simulation: Application to nuclear batteries. *Reliability Engineering & System Safety*, *228*(August), 108769. https://doi.org/10.1016/j.ress.2022.108769

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For further information, please contact
Prof. Enrico Zio, enrico.zio@polimi.it , 02 2399 6340