MSc thesis proposal with international collaboration

(in collaboration with Massachusetts Institute of Technology)

❖ Title of the research

Development of a Digital Twin of a Nuclear Microreactor: on the Multi-fidelity Uncertainty Quantification

❖ Objectives of the research

The commercialization and efficiency of future-generation nuclear reactors need *i*) dedicated advanced risk assessments to address potential hazards, threats, and vulnerabilities that may challenge both the safety and the security of the installation, *ii*) multi-physics modeling and simulation (M&S) to investigate possible accidental scenarios, evaluate the consequences and assess the risk, and *iii*) accurate real-time monitoring and health management systems to allow the nuclear reactor semi-autonomous operations. This leads to the development of Digital Twins (DTs) which are digital representations of physical assets, which embed high-fidelity simulation models, monitoring and data acquisition systems, and prognosis and health management modules (Tao et al., 2019).

Although the high-fidelity and M&S of nuclear reactors have made tremendous progress, there are always discrepancies between computer-simulated assets and real-world manufactured ones. Moreover, high-fidelity simulation models are computationally expensive and may require the use of deep learning and machine learning to the development surrogate models to speed up the simulations when investigating complex scenarios. Thus, the Uncertainty Quantification (UQ) for both the high-fidelity and the surrogate models is essential to provide measures of confidence for the risk assessment (Abdar et al., 2021).

In this context, DTs are expected to handle the uncertainty from multi-fidelity data sources (i.e., monitoring data, high-fidelity simulations and low-fidelity simulations from surrogate models) to provide reliable and robust risk assessment. The thesis aims to develop and implement an uncertainty quantification approach for DTs able to handle multi-fidelity data sources. The approach will be embedded on a DT 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 of the following steps:

- Literature review, especially on *i*) microreactors and nuclear batteries design, ii) multi-fidelity data assimilation (Cataldo et al., 2022), and iii) uncertainty quantification.
- 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

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