Second International Conference Math 2 Product (M2P 2025)
Emerging Technologies in Computational Science
for Industry, Sustainability and Innovation
June 4th-6th, 2025, Valencia, Spain

INVERSE PROBLEMS IN DIGITAL TWINS: OPTIMAL DESIGN OF EXPERIMENTS, UNCERTAINTY QUANTIFICATION AND REAL-WORLD APPLICATIONS

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ABSTRACT

Solving inverse problems is required in a wide range of engineering applications, including the calibration of a model's material parameters, damage or load identification of structures, and the localization of noise or pollutant sources. In these examples, the inverse problem mathematically articulates the integration of measurement data into a mathematical model. Thus, inverse problems enable the adjustment of models to reflect real-world conditions accurately, making them essential for creating digital twins.

Sensors generally resemble the interface between a digital model and a physical asset. Due to economic or technical constraints, only a few measurements are typically available for large, complex systems. Further information is required to infer the system's state reliably. 'Virtual sensors' promise to remedy this situation by augmenting the physical sensor measurements with physics-based simulations. In these scenarios, inverse problems arise when integrating real-world measurement data into a digital model, and in this way, digital twins can provide information about the actual system.

Uncertainty measures for inverse problem solutions are required to support informed decision-making. On the one hand, the uncertainty depends directly on the positioning and number of sensors, leading to the question of an optimal sensor placement or, more generally, an optimal design of experiments. On the other hand, high-fidelity forward models are often very resource-intensive and prevent real-time capability. Therefore, reduced models and multi-fidelity methods are used to provide reliable results and can also provide an uncertainty assessment supporting the prediction.

We welcome the contributions of researchers working on inverse problems, constrained optimization, multi-fidelity modelling, or optimal experimental design. In particular, we encourage submissions that have implemented real-world applications or provide concepts for doing so.