Feasible Data-Driven Probabilistic Modeling/Learning for Digital Twins

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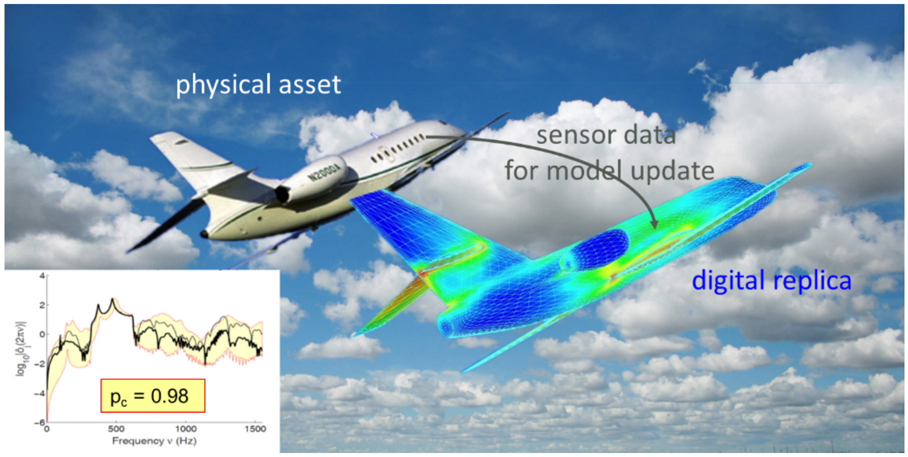

A digital twin refers to a digital replica of an asset – whether a physical platform or a process – that can be used, for example, to optimize in near real-time the operation and/or life cycle management of this asset, or more generally, to drive the Intelligent Enterprise by linking engineering and operations such as maintenance. The advocated enabler of such a computational capability is the integration of artificial intelligence, machine learning, and software analytics with data to create living digital simulation models that update and change as their physical counterparts change. Specifically, early forms of digital twins appear to be based on the integration of data analytics with model-based prediction of a few, scalar, quantities of interest (QoIs). In this lecture however, the issue of whether a system can be represented reliably by a few QoIs will be raised. Then, a more robust approach for realizing a digital twin based on adaptable, stochastic, low-order but high-fidelity computational models will be presented. This approach integrates physics-informed machine learning techniques, probabilistic reasoning, and data-driven thinking with projection-based model order reduction to construct stochastic, hyperreduced, computational models that can operate in real time and self-adapt using data extracted from physical sensors. Two sample digital twins constructed using this proposed approach – one for a small-scale replica of an X-56 type aircraft and one for a three-dimensional MEMS device – will be presented, and their real-time performance will be illustrated and analyzed.