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From Data-based engineered models to Model-based engineered data

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In the previous industrial revolution, virtual twins (emulating a physical system) were major protagonists. However, usually numerical models (virtual twins) are static, that is, they are used in the design of complex systems and their components, but they are not expected to accommodate or assimilate data. The reason is that the characteristic time of standard simulation strategies is not compatible with the real-time constraints mandatory for control purposes. Model Order Reduction techniques opened new possibilities for more efficient simulations.
A possible alternative within the MOR framework consists in extracting "offline" the most significant modes involved in the model solution, and then project the solution of "quite similar" problems in that reduced basis. Another technique, the so-called PGD, consists of calculating offline a parametric solution containing the solution of all possible scenarios.
The next generation of twins, the so-called digital twins, allowed for assimilating data collected from sensors with the main aim of identifying parameters involved in the model as well as their time evolution in real time, anticipating actions from their predictive capabilities. Thus, simulation-based control was envisaged and successfully accomplished in many applications; in many cases using low computing devices such as microprocessors and tablets. Despite an initial euphoric and jubilant period unexpected- difficulties appeared immediately. Namely, in practice significant deviations between the predicted and observed responses were noticed, limiting or abandoning their use in many applications.
Indeed, DDDAS – Dynamic Data Driven Applications Systems – consist of three main ingredients: (i) a simulation core able to solve complex mathematical problems representing physical models under real-time constraints; (ii) advanced strategies able to proceed with data-assimilation, data-curation, data-driven modelling and finally data-fusion when using compatible descriptions for the physical and data-based models; and (iii) a mechanism to adapt the model online to evolving environments (control). Hybrid Twin embraces these three functionalities into a new paradigm in simulation-based engineering sciences – SBES.

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