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Data-driven Machine Learning (ML) and Reduced Order Modeling (ROM) Approaches in Industrial Finite Element (FEA) Applications

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The field of computational mechanics is undergoing a silent revolution due to the arrival of various machine learning (ML) and reduced order modeling (ROM) technologies. The idea of combining data based and PDE based physics is essentially due to the arrival of various sensing and imaging technologies, enforced by data mining and machine learning techniques made available since as early as 1950's. These achievements are accompanied by the techniques of reduced order modeling which find their origins in the 1980's allowing for data compression and encapsulation of large discretized PDE models (FEA). Finally, the arrival of various domain decomposition and sub structuring technics within the FEA community and associated multi-processing technology also contributed greatly to both fields and have contributed to the emergence of the recent unified approaches and solver solution.

This observed revolution will probably reach a summit soon due to the combination of cloud services allowing for creation of huge data bases of model-based physics and numerically performant and computationally efficient solutions combining ML and ROM. From the computational point of view two topics are of major importance: 1) how to generate sufficient data allowing for establishment of models which represent the underlying physics and 2) how to identify « sub-structures » or more generally how to efficiently decompose models into their components or modes allowing for a disassembly of the models for efficient learning and eventual re-assembly of the responses with sufficient efficiency and precision.

In this paper we shall explore the above topics via a study of recent advances reported in the industrial FEA community. We shall present applications for linear and nonlinear (implicit and explicit) mechanics and demonstrate how various ML (supervised, non-supervised and reinforcement learning) and ROM (POD, FFT, CLUSTERING) can contribute to more efficient computational technology.

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