Convergence of Machine Learning and Finite Element methods, the smart superelements

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Abstract

In finite element analysis for structural simulation, demand for computer resources has always exceeded existing capabilities. Once engineers discovered this method, the size of engineering problems quickly grew to exceed the capacity of the existing systems. This process has repeated itself time and time again. A solution to this problem can be achieved, for many years, by using the long-time known superelements [1]. The principle used here is that the model is divided into a series of components, each of which is processed independently resulting in a set of matrices that are reduced to a boundary and describe the behavior of the component as seen by the rest of the structure. This Reduced Order Modeling approach, with a fully description by a set of stiffness, damping, mass, loads matrices, has proven for a long time to be efficient and robust [2]. Reduced simulation models decrease the computational complexity of high-fidelity engineering models, allowing for data compression and encapsulation of large discretized partial differential equation (PDE) models.

In the other hand, those last years, all the Artificial Intelligence and Machine Learning technologies and capabilities have shown dramatic growing interest and great improvements to become mature [3].

The field of computational mechanics is undergoing massive transformation due to the arrival of those various breakthrough Machine Learning (ML) and Reduced Order Modeling (ROM) technologies [4]. With the new Smart Superelement technology (SSE), MSC Nastran extends the aforementioned superelement methodology by combining it with Machine Learning to provide parameterized superelements for linear static, linear dynamic, and nonlinear analyses. The parametrized approach enables the analyst to efficiently conduct what-if studies by capturing modeling variations (i.e., material parameters, geometrical parameters, etc.) even during the initial design stages when requirements or material availability may not be finalized. Smart Superelements can be used in assembly structural models with parameters available for optimization and robustness analysis. In this paper, we shall explore the aforementioned new SSE concept after some introductions on the superelements and the machine learning technologies. We will then expose a case study in the aerospace industry using a realistic industrial aircraft finite element model.

These new techniques combined with the unprecedented availability of computing resources (e.g. cloud), provide a unique structural simulation solution, to tackle previously unattainable engineering problems.

References

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