DTE & AICOMAS 2025
Paris, France, 17 - 21 Feb 2025

A Sobolev neural network with adaptive residual weighting scheme as a surrogate for computational mechanics

Ali Kilicsoy, Marcos Valdebenito, Matthias Faes

Key words: machine learning, surrogate model, computational mechanics, sobolev training, residual weighting

ABSTRACT

In various engineering branches, such as system optimization and uncertainty quantification with regards to reliability, different sets of tools are available to evaluate system responses. Numerical models such as finite element models offer accurate evaluation of many engineering systems, albeit with computational costs that scale with system complexity. This becomes apparent when repeated evaluations of system responses are necessary for further analysis. In such cases, replacing or supporting these numerical models through use of surrogate models alleviates these computational costs. Neural networks are capable of mapping a given set of data input to a set of data responses. By making use of a small subset of responses generated by a numerical model, it is possible to train a neural network and then produce the necessary large data set through this surrogate. This reduces computational cost while maintaining feasible accuracy. Their performance can be improved by incorporating sensitivity data of the observed system per Sobolev training. Furthermore, the expansion of the neural network loss function with additional loss terms for sensitivities enables the possibility of weighting each individual term. These residual weight coefficients can be optimized with an adaptive scheme in parallel to the general neural network training, thereby improving the neural network accuracy and precision further. As a case study, such a neural network is utilized to evaluate its performance in computational mechanics.