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DeepBND: a Machine Learning approach to enhance Multiscale Solid Mechanics

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Effective properties of materials with random heterogeneous structures are typically determined by homogenising the mechanical quantity of interest in a window of observation. The entire problem setting encompasses the solution of a local PDE and some averaging formula for the quantity of interest in such domain. There are relatively standard methods in the literature to completely determine the formulation except for two choices: i) the local domain itself and the ii) boundary conditions. Hence, the modelling errors are governed by the quality of these two choices. The choice i) relates to the degree of representativeness of a microscale sample, i.e., it is essentially a statistical characteristic. Naturally, its reliability is higher as the size of the observation window becomes larger and/or the number of samples increases. On the other hand, excepting few special cases there is no automatic guideline to handle ii). Although it is known that the overall effect of boundary condition becomes less important with the size of the microscale domain, the computational cost to simulate such large problem several times might be prohibitive even for relatively small accuracy requirements. Here we introduce a machine learning procedure to select most suitable boundary conditions for multiscale problems, particularly those arising in solid mechanics. We propose the combination Reduced-Order Models and Deep Neural Networks in an offline phase, whilst the online phase consists in the very same homogenisation procedure plus one (cheap) evaluation of the trained model for boundary conditions. Hence, the method allows an implementation with minimal changes in existing codes and the use of relatively small domains without losing accuracy, which reduces the computational cost by several orders of magnitude.