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Data-driven finite element method for diffusion and transport problems

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The standard approach to mechanical problems requires the solution of the mathematical equations that describe both the conservation laws and the constitutive relations, where the latter is obtained after fitting experimental data to a certain material model. Such models range from simple linear constitutive relations with just one constant (e.g. Darcy's flow in saturated medium) to more complex ones, such as unsaturated flow, hyperelasticity or brittle fracture in heterogeneous materials, requiring setting of multiple parameters.

In this work, we follow an alternative approach [1], and develop a Data-Driven (DD) framework for mechanical problems. The conservation laws and boundary conditions are satisfied by means of the finite element method, while instead of a constitutive relationship we can use experimental data directly in simulations, thereby avoiding the need of fitting material model parameters. The developed DD framework has been implemented using open-source parallel finite element library MoFEM [2], and is applied in this study to diffusion problem in 2D which can represent flow in porous media, mass or heat transport.

Numerical tests performed with the DD framework demonstrated that the same orders of convergence (with decreasing element size and increasing approximation order) as known for standard FEM approach are obtained when the dataset includes enough data points [3]. However, the convergence with increasing number of data points is not observed when the artificially generated Gaussian noise has been added to the dataset. A promising approach to working with noisy datasets consists in obtaining the local statistical properties of distributions of data points, and using these in the computation [3].

References

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