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Proper generalized decomposition for parameter identification of porous media

The solution u to a partial differential equation (PDE) generally depends on multiple parameters, for example the coordinate $\boldsymbol{x}$, the time t, and material parameters p_1, p_2, etc. The classical way of solving a PDE involves discretization in space ($\boldsymbol{x}$) and time (t), but not in parameter space. One reason for this is the exponentially growing number of unknowns: a case with 2 parameters with 10 different values which gives $10^2 = 100$ combinations, and with 3 parameters $10^3 = 1000$ combinations. This is often referred to as *the curse of dimensionality*. Instead, when performing a parameter study, the space- and time-discretized problem is solved multiple times while varying the parameters.
Proper generalized decomposition (PGD) is a dimensionality reduction algorithm with the purpose of tackling the curse of dimensionality, see e.g. Chinesta et al.[1]. The core concept of this method is the assumption that the solution $u(\boldsymbol{x}, t, p)$ can be decomposed as follows:

$$u(\boldsymbol{x}, t, p) = \sum_{i=1}^{N} \boldsymbol{X}_i(\boldsymbol{x}) \cdot T_i(t) \cdot P_i(p), \tag{1}$$

where $\boldsymbol{X}_i$, T_i, and P_i are decoupled mode functions and N the number of "mode function products". These modes are computed in a successive enrichment process starting by computing $\boldsymbol{X}_1$ (3D), T_1 (1D), and P_1 (1D). This means that the original 5D problem have been reduced to three problems with lower dimensionalities. With this strategy it becomes easier to perform parameter studies for a large parameter space.
The goal of this project is to investigate PGD applied to a porous media (e.g. concrete, rock, asphalt, ...) problem. In addition to the standard discretization of space and time, the permeability will be added as an additional parameter to the solution.

References

[1] F. Chinesta, R. Keunings, and A. Leygue. *The Proper Generalized Decomposition for Advanced Numerical Simulations*. (2014).