Local principal component transport for reduced-order combustion modeling

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In the field of reduced-order models (ROM) for reacting flow simulations, data-driven Principal Component Analysis (PCA) has shown its effectiveness in reducing the dimensionality without losing accuracy. In particular, the PC-transport approach has been applied to different type of systems, ranging from homogeneous 0D reactors to 3D turbulent jet flames. In the PC-transport approach, the thermo-chemical state-space is parameterized using a reduced number of latent variables, the PC scores, which are transported in flow simulations instead of the original physical variables. However, those scores are defined using a global PCA basis matrix, the latter being unique for the entire PCA manifold. This global definition of the PC scores limits the achievable degree of reduction, especially in highly nonlinear data sets where a large number of scores are needed for an acceptable accuracy.

The present work seeks to enhance the PC-transport model using a local approach, where the PCA low-dimensional manifold is divided into clusters using an unsupervised algorithm based on Vector Quantization PCA (VQPCA), a PCA analysis is performed separately in each cluster providing an optimal local basis in each of them, and thereafter those local scores are transported in the simulation instead of the global scores, allowing for a higher degree of reduction. The approach is tested in homogeneous 0D reactors for different fuels using detailed chemistry.