Structure-preserving reduced-order models for parametric cross-diffusion systems

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Cross-diffusion systems are mathematical models which are used in order to account for complex diffusion phenomena in multi-species mixtures. For instance, these are used to model diffusion of various chemical species in alloys, or to model gaseous mixtures used for medical applications, in particular for respiratory assistance. They read as coupled nonlinear possibly degenerate parabolic systems and their mathematical understanding has only recently attracted the attention of mathematicians. It has recently been understood that some of these systems own a so-called entropic structure, in other words that a particular entropy functional can be seen as a Lyapunov function for such systems. The entropy-entropy dissipation relationship of this system is the key tool in understanding the long-time behaviour of the solutions of these systems. High fidelity structure-preserving finite volume numerical schemes have been developed for the simulation of such systems, but their resolution is very costly from a computational point of view, especially when parametric studies have to be performed. When it comes to model-reduction, it holds that standard Galerkin-POD reduced-order models do not preserve the mathematical properties of the system, in particular its entropic structure. The aim of this talk is to present a new Galerkin-POD type of reduced-order model for these systems, which enable to preserve all the desired mathematical properties of these cross-diffusion systems, and which is based on the choice of a particular nonlinear map specifically adapted to the entropy functional of the system. Numerical results to illustrate the behaviour, the performance and the advantages of this nonlinear structure-preserving reduced-order model will be presented.

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