ID de Contribution: **8** Type: **Non spécifié**

On structure-preserving schemes for continuum mechanics

mardi 6 juin 2023 10:30 (1 heure)

In this talk we present two new classes of structure-preserving schemes for hyperbolic and thermodynamically compatible (HTC) systems with involution constraints, which have been studied for the first time by Godunov in 1961 and later in a series of papers by Godunov & Romenski. In particular, we consider the unified first order hyperbolic model of continuum mechanics proposed by Godunov, Peshkov and Romenski (GPR) that is able to describe the behavior of moving elasto-plastic solids as well as viscous and inviscid fluids within one and the same governing PDE system. The homogeneous part of the GPR model is endowed with involution constraints, namely in the absence of source terms the distortion field A and the thermal impulse J need to remain curl-free for all times.

In the first part of this talk we present a new staggered semi-implicit structure-preserving scheme that is able to preserve the curl-free property of both fields exactly also on the discrete level. Furthermore, the pressure terms are discretized implicitly, in order to capture the low Mach number limit of the equations properly, while all other terms are discretized explicitly. Last but not least, the new staggered semi-implicit scheme is also able to reproduce the stiff relaxation limit of the governing PDE system properly, recovering an appropriate discretization of the compressible Navier-Stokes equations.

In the second part of the talk we present a new thermodynamically compatible finite volume scheme that is exactly compatible with the overdetermined structure of the model at the semi-discrete level, making use of a discrete form of the continuous formalism introduced by Godunov in 1961. A very particular feature of our new thermodynamically compatible finite volume scheme is the fact that it directly discretizes the entropy inequality, rather than the total energy conservation law. Energy conservation is instead achieved as a mere consequence of the scheme, thanks to the thermodynamically compatible discretization of all the other equations.

Computational results for several test cases are presented in order to illustrate the performance of the new schemes.

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