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Structure-preserving discretization and model order reduction of multi-phase fluid dynamical systems

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In the context of simulation of multi-phase fluid dynamical systems, a stable, efficient, and energy-preserving discretization and model order reduction framework is desirable. However, developing such a framework is traditionally challenging, particularly for problems governed by hyperbolic partial differential equations. Given the advantages of the port-Hamiltonian (pH) structure, we adopt it for developing the desired framework.

In [1], a pH formulation has been defined (implicitly in terms of extended *state-dependent* Stokes-Dirac structures) for multi-phase models for flows across constant/variable geometrical cross-sections. Several works, as in [2], have performed discretization of *state-independent* Stokes-Dirac structures. However, there is limited work in the direction of discretizing *state-dependent* Stokes-Dirac structures. A notable work in this direction is [3], which invokes a mixed Finite Element Method to obtain a *continuous-time* pH representation of the Two-Fluid Model (TFM). However, the aforementioned work associated lowest order finite element spaces without developing the framework for general choices of basis functions or discussing the impact of other possible basis functions on the existence of a *continuous-time*, finite-dimensional Dirac structure. Furthermore, the existing framework does not account for resistive effects. Hence, a general and mathematically sound framework for structure-preserving discretization and model order reduction of an extended, *state-dependent* Stokes-Dirac structure (i.e., with resistive effects) is lacking.

To this end, we develop a framework for structure-preserving discretization (and order reduction) of *state-dependent* non-linear distributed-parameter pH representations of compressible multi-phase fluid dynamics models, such as the TFM and the Drift Flux Model.

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