Model-Free Data-Driven Fracture Mechanics

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We present a model-free data-driven paradigm for variational brittle fracture mechanics where the fracture-related material modeling assumptions are removed from the formulation, while retaining the epistemic laws of fracture that stem from variational principles [1, 2]. In this approach, the fracture constitutive behavior is encoded exclusively in a discrete material data set, leading thus to a data-driven model-free approach [3]. The proposed approach can be adopted to reproduce different fracture propagation regimes, including quasi-static, rate-dependent and fatigue fracture. We consider approaches based on both local and global stability principles, fulfilling in the former case the Kuhn–Tucker conditions for the energy release rate and, in the latter, the minimization of the total free energy. The data-driven solution of the fracture mechanics problem relies on the definition of a discrete quantity, generally termed distance, which attains its minimum in correspondence of the data point that best fulfills the conditions imposed by the global and local minimization principles, leading to the data-driven counterparts of both variational principles. Furthermore, the solution is constrained so as to fulfill the crack irreversibility condition. In this non-conservative framework, the crack extension plays the role of a history variable and the proposed approach belongs to the class of differential materials [4].

The data-driven solution relying on the global minimization approach is based on the minimization of a generalized distance coinciding with the total free energy computed in correspondence of each material point. For local minimization, two alternative data-driven distances are proposed, one based on the closest-point projection of the material data set onto the (analytically known) energy-release rate function and another based on the Kuhn–Tucker conditions.

The capabilities of the approach are tested on examples with different geometries, using artificially generated material data sets, with or without random noise, which reproduce or randomize Griffith and R-curve type fracture models. Also, a convergence study with respect to the number of points and the noise amplitude of the data set is performed.

References

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