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The Inverse Finite Cell Method for Structural Identification

Tim Bürchner[1], Philipp Kopp[1], Stefan Kollmannsberger[1] and Ernst Rank[1,2,*]

[1] Chair of Computational Modeling and Simulation, Technical University of Munich, D-80333 Munich, Germany

[2] Institute for Advanced Study, Technical University of Munich, D-80333 Munich, Germany,
ernst.rank@tum.de, https://www.cms.bgu.tum.de

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Immersed Boundary Methods like the Finite Cell Method [1] or the Spectral Cell Method [2] use an indicator function α to separate the physical domain of computation from an embedding, fictitious domain Ω_{fict}. The Ansatz functions are defined on a domain-independent background mesh being defined on the union of both domains. Elements cut by the boundary are thus characterized by a jump in the indicator function, requiring special techniques for the integration of discontinuous functions.

In classical boundary value problems, the indicator function α is defined *a priori* by the geometry. A similar principle of separating geometry description and element shapes can be used for an inverse problem, where α itself is an unknown and acoustic or elastic wave propagation is considered. By discretizing α on the finite cell grid, we obtain a finite number of unknowns that we determine by minimizing an objective function that compares measured transient wave signals to the intact model-based response. As this naturally leads to a large number of optimization parameters, we use an adjoint approach for computing gradients. This idea essentially transfers the material descriptions known from topology optimization to the applications of non-destructive testing using a full waveform inversion (FWI) formulation.

The combination of FCM with FWI offers several advantages over FEM- or FD-based methods. First, we can incorporate *priori* knowledge of even very complex geometries via the immersed approach, and second, an optimization w.r.t. the indicator function α allows for high contrast of material parameters, i.e. the detection of voids or cracks. We describe the principles of this approach and show its suitability for problems of non-destructive testing on several examples.

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