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Finite Cell discretizations for Full Waveform Inversion

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Full waveform inversion (FWI) is a widely used inverse method to identify the geological features in the earth. Recently, the method has been applied also in non-destructive testing (NDT) [1]. The idea of FWI is to mathematically model the ultrasonic testing of a probe and to find the material distribution that minimizes the difference between simulated and observed (measured) signals. The spatial discretization of the material forms the set of design variables of the resulting optimization problem. A gradient based solution scheme is employed, where the gradient is computed using an adjoint method. The inversion yields a material distribution that can be used in NDT to deduce the position and shape of flaws in more detail compared to conventional methods, such as travel time tomography.

The influence of a flaw on the forward simulation is thus incorporated in the material, yet it is not explicitly discretized by the computational mesh. This resembles the approach of immersed methods, such as the finite cell method (FCM), where the geometry of a physical structure is embedded into a larger and easily meshable computational domain [2], e.g. a rectangle or a cube. The true geometry is recovered by scaling material parameters outside the geometry with a small value α. The result of FWI can thus be interpreted as an FCM-like description of the flawed geometry.

To demonstrate this connection, a plate with an unknown interior hole is considered. Measurements of acoustic signals are generated numerically. The forward problem is discretized using the p-version of the finite element method. The result of the FWI is analyzed for different transducer configurations on the boundary of the plate. It is shown, that placing a limited number of transducers on the boundary is sufficient to yield an acceptable inversion result.

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