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Identification of Uncertainties in the Geometry of Geophysical Objects

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A shape optimization method is used to reconstruct the unknown shape of geophysical layers from temperature measurements by the use of adjoint fields and level sets. The identification of the shape of the geophysical layers by temperature measurements is necessary for the efficient use of geothermal energy. Temperature is measured along thin vertical regions inside the domain, representing the boreholes. The method of speed is used to calculate the shape sensitivities, and the continuous adjoint approach is followed for the computation of the shape derivatives. Both the direct, and the adjoint problem are solved with a finite element method. The unknown shape is described with the help of the level set function; the advantage of the shape function is that no mesh movement or re-meshing is necessary but an additional Hamilton-Jacobi equation has to be solved. This equation is integrated in an artificial time, where the velocity represents the movement in the direction of the normal vector of the interface. The solution of the Hamilton-Jacobi equation is performed with essentially non-oscillatory (ENO) and weighted ENO (WENO) schemes. For large optimization steps re-initialization of the level set function is also necessary, in order to keep the magnitude of the level set function near unity, as well as to smooth the level set function. The dependence of the objective function and the quality of the recovered shape is studied with respect to the number, the position and the width of the boreholes.

These studies represent a first step in the developments of corresponding methods for multiphysics investigations, e.g., in geothermal reservoirs, where multiphase fluid flow is an important component. The necessary generalizations of our method remain a challenging task for the future.