Convergence guarantees for Newton type methods in tomographic problems via range invariance

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Abstract: A proof of convergence of iterative methods for parameter identification problems in partial differential equations PDEs from boundary measurements, as relevant, e.g., in tomographic applications, has been a long-standing open problem due to the fact that the convergence analysis of these methods can only be carried out under restrictions on the nonlinearity of the forward operator that could not be verified for such PDE coefficient identification problems so far. Likewise, although at a first glance not burdened with such restrictive assumptions on the forward operator, Tikhonov regularization requires the computation of a global minimizer of a functional whose (local) convexity can only be verified under similar restricions on the nonlinearity.
The goal of this paper is to revisit one of these conditions – range invariance of the linearized forward operator – and show that an extension of variability of the searched for parameter often allows for its verification. Since this counteracts unique identifiability of the parameter, we restore the original restricted dependency of the parameter by a proper penalization within the reconstruction method. We concretize the abstract convergence analysis in a framework typical of parameter identification in PDEs in a reduced and an all-at-once setting. This is further illustrated by some examples of coefficient identification from boundary observations in elliptic and parabolic PDEs.