Solving inverse problems without using forward operators

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Inverse problems generally speaking determine causes for desired or observed effects, which has numerous applications ranging from medical imaging via nondestructive testing to seismic prospection. Computational methods for solving inverse problems usually rely on some kind of inversion of the mentioned cause-to-effect map, which is also called forward operator. However, this forward operator is often computationally quite expensive to evaluate or might even not be well-defined. In such cases it can help a lot to take a different viewpoint and consider the inverse problem as a system of model and observation equations, with both the state of the system and the searched for parameter as unknowns. Besides such an all-at-once approach, even more generally, reformulation of the inverse problem as an optimization task rather than a (system of) equation(s) allows to avoid the use of a forward operator. A crucial aspect in the computational solution of inverse problems is their ill-posedness in the sense that small perturbations in the given observations can lead to large deviations in the reconstructions. To overcome this issue, regularization methods need to be employed and we will discuss the application and adoption of several regularization concepts to all-at-once and minimization based formulations, in contrast to classical reduced ones.