A Bird's-Eye View of Inverse Problems

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Date: 11/05/2010

Abstract

Solving an inverse problem means making inferences about physical systems from data. These inferences are based on mathematical representations of the systems, which we call models. Functionals of the models represent observable properties of the system such as the mass density as a function of space in the earth. It turns out, in order to achieve finite uncertainty in any inverse problem it is necessary to apply data-independent prior information. Thus a key aspect of inverse theory is epistemological: what does it mean to know something and how do we quantify this knowledge? Further, the classes of techniques used to solve inverse problems depend on subtle interpretations of probability that have been controversial for over a hundred years. This is the Bayes-frequentist controversy. We will steer our way through this thicket and come to a broadly useful scheme of performing inverse calculations without running aground on the shores of philosophy.