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Information sensitivity functions to assess parameter information gain and identifiability of dynamical systems

Abstract

A new class of functions, called the ‘Information sensitivity functions’ (ISFs), which quantify the information gain about the parameters through the measurements/observables of a dynamical system are presented. These functions can be easily computed through classical sensitivity functions alone and are based on Bayesian and information-theoretic approaches. While marginal information gain is quantified by decrease in differential entropy, correlations between arbitrary sets of parameters are assessed through mutual information. For individual parameters these information gains are also presented as marginal posterior variances, and, to assess the effect of correlations, as conditional variances when other parameters are given. The easy to interpret ISFs can be used to a) identify time-intervals or regions in dynamical system behaviour where information about the parameters is concentrated; b) assess the effect of measurement noise on the information gain for the parameters; c) assess whether sufficient information in an experimental protocol (input, measurements, and their frequency) is available to identify the parameters; d) assess correlation in the posterior distribution of the parameters to identify the sets of parameters that are likely to be indistinguishable; and e) assess identifiability problems for particular sets of parameters. The application of ISFs is presented in three areas of mathematical biosciences: i) a Windkessel model, which is widely used a boundary condition in computational fluid dynamics simulations of haemodynamics; ii) the Hodgkin-Huxley model for a biological neuron, which has formed the basis for a variety of ionic models describing excitable tissues; and iii) a kinetics model for the Influenza A virus.