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Fast Bayesian experimental design: Laplace-based importance sampling for the expected information gain

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Abstract

In calculating expected information gain in optimal Bayesian experimental design, the computation of the inner loop in the classical double-loop Monte Carlo requires a large number of samples and suffers from underflow if the number of samples is small. These drawbacks can be avoided by using an importance sampling approach. We present a computationally efficient method for optimal Bayesian experimental design that introduces importance sampling based on the Laplace method to the inner loop. We derive the optimal values for the method parameters in which the average computational cost is minimized for a specified error tolerance. We use three numerical examples to demonstrate the computational efficiency of our method compared with the classical double-loop Monte Carlo, and a single-loop Monte Carlo method that uses the Laplace approximation of the return value of the inner loop. The first demonstration example is a scalar problem that is linear in the uncertain parameter. The second example is a nonlinear scalar problem. The third example deals with the optimal sensor placement for an electrical impedance tomography experiment to recover the fiber orientation in laminate composites.

Keywords: Bayesian experimental design, Expected information gain, Monte Carlo, Laplace approximation, Importance sampling, Composite materials.

AMS 2010 subject classification: 62K05, 65N21, 65C60, 65C05

1. Introduction

This work proposes an efficient method for the computation of expected information gain [1–3] appearing in optimal Bayesian experimental design. The expected information gain,

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