

Sequential Experimental Design for Predator-Prey Models

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1 Motivation

motivation

2 Methodology

2.1 part one

The overarching goal of the sequential experimental design presented in this paper is to efficiently identify the correct functional response model and precisely estimate its parameters. Achieving this goal requires balancing statistical accuracy with computational feasibility.

2.2 Challenge of Bayesian Inference

The Sequential Experimental Design framework relies on Bayesian inference, which necessitates accurately tracking the posterior distribution of the model parameters. Calculating this high-dimensional posterior analytically is computationally intractable. Necessity of Simulation: To overcome this, the algorithm employs Sequential Monte Carlo (SMC) methods, which approximate the continuous posterior distribution using a discrete set of N particles.

2.3 Experiment 1: Sensitivity Analysis

The Particle Problem: The accuracy of this approximation, and thus the reliability of the entire sequential design, is directly tied to the number of particles, N .

Therefore we deployed a sensitivity analysis with the motivation to rigorously validate the selection of the particle count N used by the authors (**N = 500**).

The goal was to quantify and observe the trade-off between lower and higher, particle size, where lower particle quantities result in shorter compute time but unstable, low-resolution posterior distributions that yield unreliable sequential design choices. We hypothesized that while a statistically optimal N value exists (yielding minimum noise), the practical choice (**N = 500**) must represent the highest particle count that is feasible within typical resource constraints. Therefore, we conducted a sensitivity analysis on $N \in \{30, 100, 500, 1000\}$ to examine the author's choice of $N = 500$.

2.4 Experiment 2: Determining the Best Method of Selecting Design Points

One of the purposes of the study involved looking at methods of choosing design points for a predator-prey experiment. Design points are simply the experimental conditions, and in this case, the initial number of prey. The authors lay out a total of six methods, but in this experiment, only two were explored with the addition of a new method. The first method ($R=0$) involves selecting a design point randomly every experiment, and the second ($R=1$) selects a design point that maximizes utility for parameter estimation. We introduced a third method ($R=6$), which involves selecting all of the design points for every experiment up-front. Under this method, design points can not be updated as experiments progress, but also better reflects realistic experimental design as researchers may need to know their resources and timelines before beginning their experimentation.

For this experiment, the true model was set to Beta Binomial Type II (Model 1). Due the computational weight of method 1, the number of iterations was scaled down to 10, and the number of particles to 200. The true parameters for a , T_h , and λ , were kept at 0.5, 0.7, and 0.5, respectively.

2.5 Experiment 3: Two-step Move Step

Sequential Monte Carlo involves taking weighted samples (particles) and iteratively changing them to more closely match a target distribution. To get a new posterior distribution for each iteration of Sequential Monte Carlo, each particle is re-weighted. These weights are often skewed, however, and the effective sample size is reduced. When the effective sample size is below a threshold ($N/2$ in the case of this study), it is best to re-sample and conduct a move step to diversify the particles, since duplicates often occur. The move step shifts particles according to probabilities in a Markov Chain Monte Carlo Kernel. Moffat et al. (2020) uses one move step, but outlines that is may be too few to diversify the particle set. The appropriate amount of times to conduct a move step for each particle is outlined as:

$$R_m \geq \frac{\log c}{\log(1-p)}$$

where c is a pre-selected probability for the particle to move and p is acceptance probability. There are cases where this inequality is not true, and one move step is not sufficient. Thus, in this experiment, we study the effects of using two move steps after each re-sampling. We know that having two steps increases the uniqueness of the particle set and that the probability is greater for each particle to move with two rounds. Because of this, we aim to find whether diversifying the particles will improve the random models' posterior distributions.

3 Results

3.1 Results: Experiment 2

3.1.1 Parameter Estimation

4 References

Moffat Hayden, Hainy Markus, Papanikolaou Nikos E. and Drovandi Christopher 2020 Sequential experimental design for predator-prey functional response experiments J. R. Soc. Interface.1720200156 <http://doi.org/10.1093/Interface/afaa056>

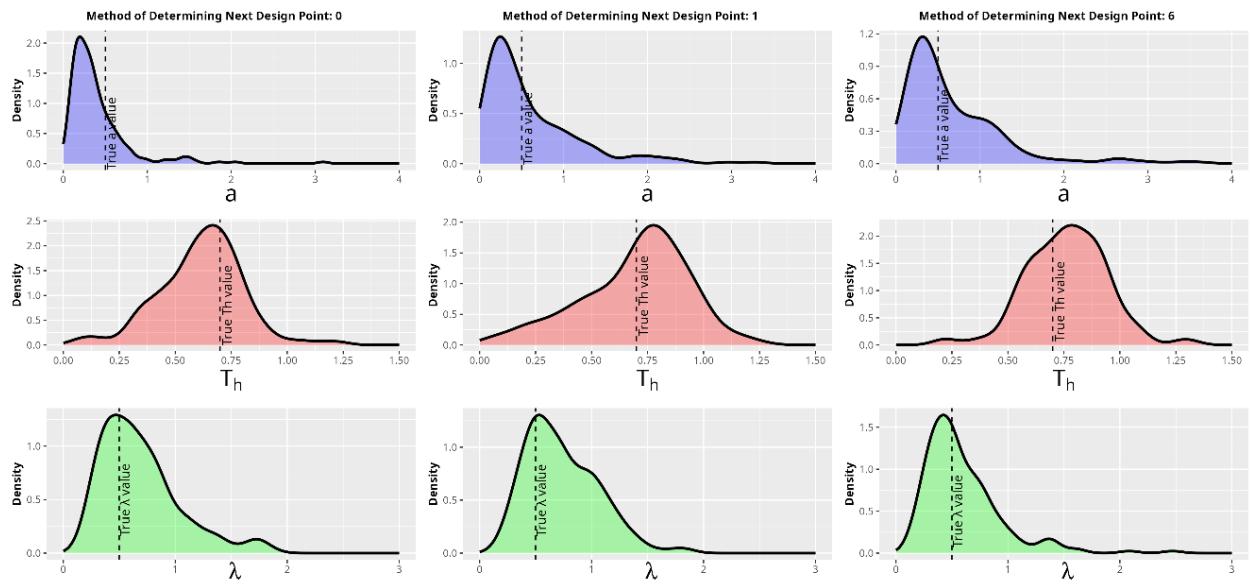


Figure 1: Figure N

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