Optimal Experimental Design: Psychophysics of change point Detection.

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Abstract

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1. Introduction

When we have a new research question, we face the problem of designing an experiment in order to address it. Typically, one start's by making decisions about the number of participants, how many and what values of our independent variable should we test or how many times should we test each of those values. Most of the time, these choices are made on the basis of previous research on the field. However, it might be the case that there is not enough information on the literature to make these decisions with confidence, or that the values that are commonly used, do not allow for strong conclusions. Optimal Experimental Design (OED) offers an statistical alternative to solve this kind of problems.

2. OUTLINE

Experimental design First we need a research question, then the prolem of designin the experiment arises, how many participants should we test, what are the values of the independent variable that we should use, how many times should we present each of those values, etc. The problem is when

2.1. Optimal experimental design

Elements:

Design space: what are the elements of the experimental design that we want to optimize Utility Function: function that maps points on the design space to the real numbers, this function should reflect the objective of the experiment, for example if we want to discriminate between two cognitive models, the utility function should assign a greater value to an experimental design for which the models give different predictions that to designs for which the predictions of the models are indistinguishable from one another.

3. Optimal Experimental Design: Example

Why is is detecting changes important for an organism?

Change detection in probabilistic series.

Arising problems with experimental design.

Research question and its statistichal interpretation

Assumtion about the relationship between a subjects response the dependent variable under study

Design space for this problem and how to reduce the dimensionality of the space by assuming experimental constraints.

Utility function and its relationship with the objective of the experiment

Arising problems with utility function and the proposed response function. Bayesian solution, assigning a prior distribution to the parameters, the less research in a field the more difficult it is to assign an informative prior, however, we could use other cognitive models in order to propose a prior distribution.

3.1. Using a model to generate prior distributions

Using the prior distribution, the utility function and the definition of a design space we can otimize the experimental design in this case we are looking for $\delta\theta^*$ that maximizes the following equation:

$$U(\delta\theta^*) = \max_{\delta\theta} \int_{\beta} log(det(I(\beta|\delta\theta)))\pi(\beta)d\beta \tag{1}$$

The previous integral can be approximated via Monte Carlo sampling

4. Results

4.1. Consruction of the prior distribution

Prior over model parameters(Gallistel et al 2014) Results Constructing the prior: we take a multivariate normal distribution with mean and covariance equal to the unbiased estimators for both parameters.

4.2. Optimal design

Aproximating the utility function (integral) throught Monte Carlo simulation Utility aproximation for 2 Design points

the approximation returns a smooth curve over the 2 point design space.

5. Discussion

Optimal design for the example Properties of the most useful points (they land on the points of the curve where the steepness changes most dramatically)

Advantages of Optimal Design

Using models to generte prior distributions.