Banff Challenge Problem 1 for PHYSTAT 2011

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This is a brief description of the method used to address the first Banff challenge problem for PHYSTAT 2011 meeting. The method is based on the principle of Bayes' Theorem and takes advantage of the Bayesian Analysis Toolkit (BAT) package [1].

We start with a background only fit to the data and make the decision if it would make sense to include a signal hypothesis based on the fit result. We use 100 bins for data, and do a fit using a product of Poisson distributions. We consider a truncated Gaussian prior for the background rate, A, with a range of 0 to 20000.

The decision to claim a discovery is split into two parts. The first one is made based on a p-value calculation performed by the BAT's fast Poisson p-value estimation, corrected for number of degrees of freedom, see Apendix in [2], in this case just 1 degree of freedom. To calculate the p-value, we use the value of A that maximizes the posterior probability in the background only case. For p-values smaller than 0.01, we look further into the dataset to examine the presence of a signal. We then evaluate the probability of background only using $P(D|B)$ and $P(D|B,S)$ where they are the probability of the data assuming only background and the probability of the data assuming background+signal, respectively. We address the "Look Elsewhere Effect" by assuming a prior that favours the background model, namely $P_0(B) = 0.95$, $P_0(S) = 0.05$. Once we assume the presence of a signal, we need to set up the priors for the signal rate, D, and the peak position, E, as the width is fixed. We choose a flat prior for both E and D. The range for D is 0 to 2000 and E is between 0 and 1. We continue to use the truncated Gaussian prior for A.

The posterior probability for background only is

$$P(B|D) = \frac{P(D|B)P_0(B)}{P(D|B)P_0(B) + P(D|B,S)P_0(S)} \tag{1}$$

that is calculated through integration over the respective parameter space using ROOT AdaptiveIntegrator routines. We claim a signal discovery if $P(B|D)$ <0.001, and then in this case, we fit for the peak location and the signal rate. We estimate the peak position, the central 68% credibility interval for the peak location and the signal rate using a Markov Chain Monte Carlo (MCMC) algorithm implemented within BAT. We run three Markov Chains, convergence is determined by Gelman-Rubin R-value. After convergence has been declared we run each chain for 3500 iterations to collect samples of the posterior. We record the best fit parameter values as the chains progress and use those as the starting point for ROOT Minuit. We store the 1-D marginalized distributions for D and E in histograms with 1000 bins to estimate the 68% credibility intervals. Minuit is only used to get the best fit parameters and not to estimate the uncertainties.

We present the result of our analysis in an ASCII file with the following information in the columns:

- Dataset Number
- Decision to claim evidence for H_1 over H_0
- p-value used to make the first filtering of datasets
- $P(B|D)$ used to claim the discovery (we quote 0 if p-value$>$0.01)
- Best estimate of D
- Lower edge of the credibility interval for D
- Upper edge of the credibility interval for D
- Best estimate of E
- Lower edge of the credibility interval for E
- Upper edge of the credibility interval for E

References

[1] A. Caldwell, D. Kollar, K. Kröninger, ‘BAT - The Bayesian Analysis Toolkit’, Comput. Phys. Commun. **180** (2009) 2197.

[2] F. Beaujean *et al.*, ‘p-values for Model Evaluation‘, arXiv:1011.1674v1.