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Approximating Likelihood Ratios with Calibrated Classifiers

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Likelihood ratio tests are a well established technique for statistical inference in HEP. Because of the complicated detector response, we usually cannot evaluate the likelihood function directly. Instead, we usually build templates based on (Monte Carlo) samples from a simulator (or generative model). However, this approach doesn't scale well to high dimensional observations.

We describe a technique that is an generalization of HEP usage of machine learning for discrete signal vs. background classification to a situation with continuous parameters. We use the simulator to describe the complex processes that tie parameters θ of an underlying theory and measurement apparatus to the observations. we show that likelihood ratios are invariant under a specific class of dimensionality reduction maps ℝˆp ↦ ℝ. As a direct consequence, we show that discriminative classifiers can be used to approximate the generalized likelihood ratio statistic when only a generative model for the data is available.

We have implemented the method in 'carl', a python based package that extends the interfaces of scikit-learn and also takes advantage of theano for the implementation of simple generative models.

The method has many applications as it extends our traditional likelihood-based measurements to high-dimensional inputs. The likelihood ratio can also be used for multivariate reweighting and as a goodness of fit statistic. Experimental results on artificial problems with known exact likelihoods illustrate the potential of the proposed method. We also have preliminary results applying the method to Higgs Effective Field Theory.

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