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Hunting for signals using Gaussian Process regression

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We present a novel computational approach for extracting weak signals, whose exact location and width may be unknown, from complex background distributions with an arbitrary functional form. We focus on datasets that can be naturally presented as binned integer counts, demonstrating our approach on the datasets from the Large Hadron Collider. Our approach is based on Gaussian Process (GP) regression - a powerful and flexible machine learning technique that allowed us to model the background without specifying its functional form explicitly, and to separate the background and signal contributions in a robust and reproducible manner. Unlike functional fits, our GP-regression-based approach does not need to be constantly updated as more data becomes available. We discuss how to select the GP kernel type, considering trade-offs between kernel complexity and its ability to capture the features of the background distribution. We show that our GP framework can be used to detect the Higgs boson resonance in the data with more statistical significance than a polynomial fit specifically tailored to the dataset. Finally, we use Markov Chain Monte Carlo (MCMC) sampling to confirm the statistical significance of the extracted Higgs signature.

Significance

Efficient and accurate background estimation is one of the most crucial aspects of searching for new physics or studying rare physics. Non-resonant backgrounds involving Quantum Chromodynamic processes are often very challenging to estimate. Conventionally these backgrounds are estimated using ad-hoc function fitting, which often fails in the presence of signals with smaller magnitudes or larger data.

Here we present a novel approach using machine learning techniques such as Gaussian Process regression and Bayesian framework to hunt for new physics. This approach is shown to be sensitive and well functioning in the ever-increasing dataset of experimental particle physics.

References

https://arxiv.org/abs/2202.05856

Experiment context, if any

This presentation is regarding the background estimation procedure used in experimental high energy physics.

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