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Design by intelligent committee: use of machine learning as a scientific advisor

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Experimental measurements in high energy physics are primarily designed using the expert knowledge and intuition of the analysers, who define their background rejection cuts, control/signal regions and observables of interest based on their understanding of the physical processes involved. More recently, modern multivariate analysis techniques such as neural density estimation and boosted decision trees have allowed analysers to interpret their data in a way which sets highly-optimised limits on specific new physics models. However, in all experiments where data is costly, a high value is placed on model-independent measurements which characterise the data in a way which captures the salient features of the physical processes involved, but without assuming any new physics model in particular.

We demonstrate the use of neural density estimation as an "insight extractor", capable of advising the analyser about which observables take precedence when constraining benchmark models, and further suggesting optimal selection criteria. The analyser can then design their experimental measurements ensuring that no potentially-sensitive observations are neglected, whilst the measurements themselves remain model-independent. Such an approach leverages the ability of neural networks to capture high dimensional dependencies in both the observable and parameter spaces. As an exploratory example, we consider the design of differential cross section measurements that can be used to constrain models of new phenomena, using data on the electroweak production of Z bosons in association with two jets interpreted using the Standard Model effective field theory (EFT) as a benchmark model. This approach can equally be applied in both EFT frameworks and complete beyond-the-Standard-Model theories to enhance the potential for scientific discovery.

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