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Are Differentiable Simulators Beneficial for Cosmological Simulation-Based Inference?

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In many physical problems, the marginal likelihood of the data given physical parameters is intractable, making the inference of these parameters from data challenging. Simulation-Based Inference has emerged as a rigorous solution for solving this inference problem requiring only a black-box simulator. An ongoing research direction is to improve sample efficiency, which is especially relevant in Cosmology where simulations are very costly.
We present our work on leveraging automatic differentiability of simulators to help reduce the number of simulations, an idea introduced as Gold Mining (Brehmer et al. 2019). We have in particular developed Neural Posterior Estimation methods that can benefit from accessing the simulator's gradients and find that this approach does help on some problems (e.g. Lokta-Voltera). We then further investigate the practical gains of Gold Mining on a simplified Cosmological inference problem emulating a weak lensing analysis of LSST-Y10 data. We show how the amount of additional information provided by the simulator's gradients is problem-dependent and, alas, not always significant. In our cosmological problem, we find that while having access to a differentiable simulator does have some benefits (e.g. HMC sampling of joint log-likelihoodl), it does not help SBI methods since gradient information is dominated by noise.

Brainstorming idea [title]

What is the most promising avenue for using differentiable simulators for inference?

Brainstorming idea [abstract]

We show that, depending on the problem, for SBI the score of the simulation can be dominated by the stochasticity induced by the latent variables of a simulator, and thus carry little information about the posterior of interest. On the other hand, HMC methods certainly benefit from score information but are slow and struggle to explore the full (potentially multi-modal) posterior of the latent variables of the model, which can induce biases in the marginal inference of the parameters of interest.

Given all the recent developments of inference techniques around diffusion models, are there potentially new avenues for exploiting score information from differentiable simulators for inference? Or could we find other avenues to cure the limitations of current methods.

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