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Physics-Conditioned Diffusion Models for Lattice Gauge Field Theory

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We develop diffusion models for simulating lattice gauge theories, where stochastic quantization is explicitly incorporated as a physical condition for sampling. We demonstrate the application of this novel sampler to U(1) gauge theory in two spacetime dimensions and find that a model trained at a small inverse coupling constant can be extrapolated to larger inverse coupling regions without encountering the topological freezing problem. Additionally, the trained model can be employed to sample configurations on different lattice sizes without requiring further training. The exactness of the generated samples is ensured by incorporating Metropolis-adjusted Langevin dynamics into the generation process. Furthermore, we demonstrate that this approach enables more efficient sampling of topological quantities compared to traditional algorithms such as hybrid Monte Carlo and Langevin simulations.

Primary authors: ZHU, Qianteng (RIKEN / Shanghai Jiao Tong University); WANG, Lingxiao (RIKEN)

Co-authors: AARTS, Gert (Swansea University); Prof. ZHOU, Kai (CUHK-Shenzhen); Prof. WANG, Wei (SJTU)

Presenter: ZHU, Qianteng (RIKEN / Shanghai Jiao Tong University)

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