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CaloPointFlow - Generating Calorimeter Showers as Point Clouds

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In particle physics, precise simulations of the interaction processes in calorimeters are essential for scientific discovery. However, accurate simulations using GEANT4 are computationally very expensive and pose a major challenge for the future of particle physics. In this study, we apply the CaloPointFlow model, a novel generative model based on normalizing flows, to fast and high-fidelity calorimeter shower generation. We use the CaloPointFlow model, an adapted version of the PointFlow model for 3D shape generation, to generate calorimeter showers using point clouds that exploit the sparsity and leverage the geometry of the data. We preprocess the voxelized datasets of the Fast Calorimeter Simulation Challenge 2022 to point clouds and apply the CaloPointFlow model to all three datasets without any adaptation. Furthermore, we evaluate the performance of our model on metrics such as energy resolution, longitudinal and transverse shower profiles, and shower shapes, and compare it with GEANT4. We demonstrate that our model can produce realistic and diverse samples with a sampling time of around 30 million single 4D points per minute. However, the model also has some limitations, such as its inability to capture the point-to-point correlation and its generation of multiple points per cell, which are in contradiction to the data. To address these issues, we propose a novel method that uses a second sampling step to compute the marginal likelihoods of each cell being hit and sample the energies accordingly. We also discuss some ideas on how to handle the point-to-point correlations in future work. The main strengths of our model are its ability to handle diverse datasets, its fast and stable convergence, and its highly efficient point production.

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