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CaloMan: Fast generation of calorimeter showers with density estimation on learned manifolds

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The efficient simulation of particle propagation and interaction within the detectors of the Large Hadron Collider (LHC) is of primary importance for precision measurements and new physics searches. The most computationally expensive step of the simulation pipeline is the generation of calorimeter showers, and will become ever more costly and high-dimensional as the LHC moves into its high luminosity era. Modern generative networks show great promise to become vastly faster calorimeter shower emulator altertnatives, as shown by a number of architecutres proposed in the context of the Fast Calorimeter Simulation Challenge 2022. Among them, Normalizing Flows (NFs) appear to be a particularly precise option. However, the bijective nature of the NFs tampers with their scalability. We thus propose a two-step approach for calorimer shower simulation: first we learn a lower-dimensional manifold structure with an auto-encoder, and then perform density estimation on this manifold with a NF. Our approach, lies on the notion that the seemingly high-dimensional data of high energy physics experiments, actually has a much lower intrinsic dimensionality. In machine learning, this is known as the manifold hypothesis, which states that high-dimensional data is supported on low-dimensional manifolds. By reducing the dimensionality of the data we enable faster training and generation of high-dimensional data.

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