T 86: ML Methods IV

Time: Wednesday 17:30–19:00 Location: HSZ/0405

T 86.1 Wed 17:30 HSZ/0405

EPiC-GAN: Equivariant Point Cloud Generation for Particle Jets — •Erik Buhmann — Institut für Experimentalphysik, Universität Hamburg

With current and future high-energy collider experiments' vast data-collecting capabilities comes an increasing demand for computationally efficient simulations. Generative machine learning models allow fast event generation, yet so far are largely constrained to fixed data and detector geometries. We introduce the Deep Sets-based equivariant point cloud generative adversarial network (EPiC-GAN) for the generation of point clouds with variable cardinality – a flexible data structure optimal for collider events such as jets. The generator and discriminator utilize multiple EPiC layers with an interpretable global latent vector and do not rely on pairwise information sharing between particles, leading to a significant speed-up over graph- and transformer-based approaches. We show that our GAN scales well to large particle multiplicities and achieves high generation fidelity for gluon, light quark, and top jets.

T 86.2 Wed 17:45 HSZ/0405

Development of novel machine learning algorithms for robust jet flavour classification for Run3 at CMS — •Annika Stein[1], Judith Bennertz[1], Xavier Coubez[1,2], Alexander Jung[1], Summer Kassem[1], Ming-Yan Lee[1], Spandan Mondal[1], Alexandre de Moor[3], Andrzej Novak[1], Alexander Schmidt[1], and Hendrik Schönen[1] — [1]III. Physikalisches Institut A, RWTH Aachen University, Aachen, Germany — [2]Brown University, Providence, USA — [3]Vrije Universiteit Brussel, Brussels, Belgium

Complex neural network architectures have been developed for jet tagging and play a crucial role for numerous analyses relying on this classification task. Recent advances exploit low-level information with convolutional layers, graph neural networks, or transformer models with attention mechanisms. While improving performance is one of the key components in tagger development, the capability to generalize to detector data imposes new challenges and can be probed through comparisons between the two domains, simulation and data, in different phase spaces. This talk will showcase how strategies like adversarial training can be used to improve robustness and data/MC agreement for state-of-the-art tagging algorithms. An overview of the upcoming generation of flavour tagging algorithms for Run3 will be given.

T 86.3 Wed 18:00 HSZ/0405

Deep Neural Networks for jet-flavor tagging based on different hadronization models — •Aritra Bal, Markus Klute, and Roger Wolf — Institute for Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Differences between the samples of either quark- or gluon-initiated jets produced by the two Monte-Carlo event generators Pythia and Herwig have been reported in the literature. A neural network can be trained to perform jet-flavor tagging on samples from either MC generator, but the performance of the network is observed to depend on the sample to which it is applied, and a network applied to a Herwig sample performs better than when applied to a Pythia sample, irrespective of the sample it was originally trained on.

We train a neural network using simple kinematic, and high-level constructed variables for better discrimination, to tag jets based on their flavor (as quark or gluon). A thorough analysis of the dependence on the input space is performed, to examine how the network responds to samples generated using different hadronization models. We also identify the critical regions of the input space where the two generators differ in the neural network response, using a Taylor Series expansion of the output function (up to 2nd order) in terms of the input variables, which we then use to find one possible answer for the generator dependence observed in the neural network application.

T 86.4 Wed 18:15 HSZ/0405

Multi-parameter Conditioning of Generative Models for Fast Simulation of Highly Granular Calorimeter Showers — •Peter McKeown — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

High fidelity detector simulation is crucial for modern high energy physics experiments. While traditional simulation tools based on Monte Carlo methods are powerful, they consume significant computational resources. For this reason at the upcoming high luminosity stage of the LHC and for future colliders, simulation is expected to produce a major computational bottleneck. Particle showers in calorimeters are particularly computationally intensive due to the many interactions that occur with the detector material. Given the vast increases in the granularity of these detectors for future experiments, a high degree of fidelity is required of a surrogate simulator.

Deep generative models hold promise to provide significantly faster, yet accurate, simulation tools. Significant progress has been made in the simulation of both electromagnetic and hadronic showers in highly granular calorimeters. However challenges remain when broadening the scope of these simulators. In particular, these tools must be able to accept multiple conditioning parameters, for example to be able to handle particles incident at arbitrary angles. This talk will review the development of such a simulation tool, with a particular focus on the high degree of physical fidelity achieved, as well as the performance after interfacing with reconstruction algorithms.

T 86.5 Wed 18:30 HSZ/0405

Super-resolution of photon calorimeter images using generative adversarial networks — Johannes Erdmann[1], Aaron van der Graaf[2], •Florian Mausolf[1], and Olaf Nackenhorst[2] — [1]III. Physikalisches Institut A, RWTH Aachen University — [2]TU Dortmund University, Department of Physics

Photons are important objects at collider experiments as, for example, the Higgs boson can be studied with high precision in the diphoton decay channel. For this purpose, it is crucial to achieve the best possible spatial resolution for photons and to discriminate against other particles which can mimic the photon signature.

In this talk, a method to generate photon calorimeter images at increased resolution is presented. The energy depositions of single photons and photon pairs from neutral pion decays are simulated in a lead tungstate crystal calorimeter. Each shower is obtained pairwise, for a calorimeter with a crystal width of 2.2 cm and for a calorimeter with higher resolution, where the number of crystals is increased by a factor of 16. Wasserstein generative adversarial networks are trained to estimate the high-resolution images from their low-resolution counterparts, with a deep residual convolutional neural network used as generator. The properties of the super-resolved calorimeter images are analysed and it is shown that their barycentres can be significantly better localised in the calorimeter. Moreover, classifiers are trained on either super-resolution or low-resolution images to separate single photons from neutral pion decays and their performances are compared.

T 86.6 Wed 18:45 HSZ/0405

Generative Modeling with Diffusion Neural Networks for Fast Simulation of Electromagnetic Showers in the International Large Detector — •Anatolii Korol — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

In high energy physics, detailed and time-consuming simulations are used for particle interactions with detectors. For future experiments and the upcoming High-Luminosity phase of the Large Hadron Collider (HL-LHC), the computational costs of conventional simulation tools are expected to exceed the projected computational resources.

Generative neural networks (GNNs) have the potential to provide a fast and accurate alternative. So far most of the studies of GNNs for fast simulations have used data represented in the form of a regular grid since it is possible to apply modern machine learning algorithms from image processing that are well optimized and developed.

In fast simulations with GNNs, it is crucial to be able to place GNNs into the simulation pipeline, and since many of today*s detector systems are not regular in terms of the positions of the active cells, it*s very hard to represent the data in a form suitable for training the GNN.

This work focuses on the development of a GNN for speeding up the simulation of electromagnetic showers in the electromagnetic calorimeter of the International Large Detector (ILD). In particular, a Diffusion Model is trained on Geant4 steps, where the electromagnetic shower is presented as a 3D point cloud to avoid the irregularities of the detector geometry and thereby generate showers anywhere in the calorimeter.