Generative Models in Simulations for High Energy Physics.

Viktoria Chekalina[1,2], Elena Orlova[3], Fedor Ratnikov[1,2], Andrey Ustyuzhanin[1,2] and Egor Zakharov[3]

[1]*NRU Higher School of Economics, Moscow, Russia*
[2]*Yandex School of Data Analysis, Moscow, Russia*
[3]*Skolkovo Institute of Science and Technology, Moscow, Russia*

High Energy Physics experiments are aimed to shed light on open problems of the fundamental structure of the matter and the Universe. For the simplicity sake but without loss of generality, we consider an example of Large Hadron Collider (LHC) detector. A detailed simulation of the experiment includes modelling beam, the interaction of accelerated particles, production of the Standard Model and New Physics particles, prompt decays, an interaction of a particle with detectors, emulation of readout electronics and so on. All this work is the vital component for a reliable interpretation of the observed results, extracting new knowledge about the fundamental laws of the Universe.

The goal of obtaining more precise results in the current LHC experiments drives the plans to increase the instantaneous luminosity observed by the detectors significantly. Another complexity factor is the growth of the number of protons colliding at each moment in time, thus increasing the complexity of observed events. Which in turn, leads to the development of advanced approaches to triggering, reconstruction, analysis and event simulation. The latter task brings to a critical challenge: generating the significantly higher amount of Monte Carlo (MC) data, required for an analysis of the data collected at the higher luminosity, without a drastic increase in computing resources requires a significant speedup of the simulation algorithms. GEANT modelling of particles interacting with the material of the detector, in particular, the shower development in electromagnetic and hadronic calorimeters takes the most significant part of computer simulation resources.

In this research, we present the possibilities to accelerate these simulation computations by using methods of sample generation by Neural Networks. Such models are widely used for computer vision and image processing nowadays. There are two main approaches to this problem: Generative Adversarial Networks (GAN), that takes into account explicit description of the real data, and Variational Autoencoders (VAE), that uses latent variables to describe the ones. Finally, we compare both approaches for the calorimeter simulation for the LHCb experiment at LHC, discuss possible problems and advantages of these approaches.