AKPIK 4: Deep Learning

Time: Thursday 16:15–18:30 Location: AKPIK-H13

AKPIK 4.1 Thu 16:15 AKPIK-H13

Using Graph Neural Networks for improving Cosmic-Ray Composition Analysis at IceCube Observatory — •Paras Koundal for the IceCube-Collaboration — Institute for Astroparticle Physics, KIT Karlsruhe, Germany

Graph Neural Networks (GNNs) is one of the most emerging and promising research topics in the field of deep-learning. Described using nodes and edges, graphs allow us to efficiently represent relational data and learn hidden representations of input data to obtain better model-prediction accuracy. The success of GNNs is mainly attributed to their unique ability to represent complex input data in its most natural representation. GNNs have hence accelerated and extended the pattern learning, inference drawing of standard deep-learning architectures. This has also made it possible for faster and more precise analysis in astroparticle physics, enabling new insights from massive volumes of input data. IceCube Neutrino Observatory, a multi-component detector concealed deep under the South Pole ice provides a suitable test-case to implement such methods.

The talk will discuss the GNN-based methods for improving cosmic-ray composition understanding in the transition region from Galactic to extragalactic sources, at IceCube Observatory. The implementation benefits by using full signal-footprint information, in addition to reconstructed cosmic-ray air shower parameters. The talk will also explain improvement to individual GNN based model by ensemble methods. The implementation will reduce the time and computing cost for performing cosmic-ray composition analysis while boosting sensitivity.

AKPIK 4.2 Thu 16:30 AKPIK-H13

Amplifying Calorimeter Simulations with Deep Neural Networks — •Sebastian Guido Bieringer[1], Anja Butter[2], Sascha Diefenbacher[1], Engin Eren[3], Frank Gaede[3], Daniel Hundshausen[1], Gregor Kasieczka[1], Benjamin Nachman[4], Tilman Plehn[2], and Mathias Trabs[5] — [1]Institut für Experimentalphysik, Universität Hamburg, Germany — [2]Institut für Theoretische Physik, Universität Heidelberg, Germany — [3]Deutsches Elektronen-Synchrotron, Hamburg, Germany — [4]Physics Division, Lawrence Berkeley National Laboratory, Berkeley, CA, USA — [5]Fachbereich Mathematik, Universität Hamburg, Germany

Speeding up detector simulation over the computationally expensive Monte Carlo tools is a key effort for upcoming studies at the LHC and future colliders. Machine-learned generative surrogate models show great potential to accelerate such and other simulations. However, estimating the relation between the statistics of the training data and the generated distribution of the model is essential to determine the gains and use-cases of these methods.

We present a detailed study of this relation for the concrete physics example of photon showers in a highly granular calorimeter. For established metrics on calorimeter images, the amplification properties of a VAE-GAN model are examined in terms of an approximation to the Jenson-Shannon-divergence between generated data, training data and a high-statistics batch.

AKPIK 4.3 Thu 16:45 AKPIK-H13

Deep Learning-based Imaging in Radio Interferometry — •Felix Geyer and Kevin Schmidt — Astroparticle Physics AG Elsässer, TU Dortmund University, Germany

Radio interferometry is used to monitor and observe distant astronomical sources and objects with high resolution. Especially Very Long Baseline Interferometry allows achieving the highest resolutions by combining the data of multiple telescopes. This results in an effective diameter corresponding to the greatest distance between two telescopes. The taken data consists of visibilities, which depend on the baselines between the telescopes. Because the distribution of these baselines is sparse, the sample of visibilities is incomplete. After transforming this sample to spatial space, this so-called "dirty image" is inadequate for physical analyses. Thus, the image undergoes an elongated and mostly manually performed cleaning process in order to remove background artifacts and to restore the original source distribution. We developed a new and fast approach to reconstruct missing data reasonably using Neural Networks. This talk will present the current state of the `radionets` framework and an outlook on upcoming projects. One focus will be on the simulation improvements using the RIME formalism.

AKPIK 4.4 Thu 17:00 AKPIK-H13

Binary Black Hole Parameter Reconstruction using Deep Neural Networks — •Markus Bachlechner, David Bertram, and Achim Stahl — III. Physikalisches Institut B, RWTH Aachen

The proposed Einstein Telescope, as the first of the third generation of gravitational wave detectors, is expected to be an order of magnitude more sensitive compared to current interferometers like LIGO or Virgo. On the one hand the higher sensitivity increases the observable volume. On other hand the frequency range is broadened, which in return bares the potential to extend the observable time of binary coalescences from seconds to hours. These long observable times make it possible to send multi-messenger alerts before the end of the coalescences. For this it is essential to apply a fast real-time analysis handling event detection, classification, and reconstruction. In this talk an approach for the parameter reconstruction of binary black holes using deep neural networks is presented.

AKPIK 4.5 Thu 17:15 AKPIK-H13

A Recurrent Neural Network for Radio Imaging — •Stefan Fröse and Kevin Schmidt — Astroparticle Physics WG Elsässer, TU Dortmund University, Germany

In radio astronomy, an array of correlated antennas, called a radio interferometer, is used to produce high-resolution images of the sky. The measurements take place in the complex Fourier space due to the pairwise correlation of antennas. Therefore, the amount of information to receive from such an array is restricted by the number of antennas. The resulting spatial dirty map of these measurements will be cleaned using a Neural Network. The architecture for this network is based on a Recurrent Neural Network (RNN). RNNs can be used to extract information from sequential data, like text or speech. In the context of inverse problems the RNN can be derived directly from a *maximum a posteriori* approach. Furthermore the iterative behaviour of the network can be exploited to construct a `CLEAN`-like network to reconstruct a map of the sky. This results in the so-called `RIM` architecture published by Patrick Putzky & Max Welling (arxiv:1706.04008). The Neural Network is able to clean given dirty maps for simulated radio images and also shows convergence for the EHT dataset of M87.

AKPIK 4.6 Thu 17:30 AKPIK-H13

Measurement of the Mass Composition using the Surface Detector of the Pierre Auger Observatory and Deep Learning — Martin Erdmann, •Jonas Glombitza, and Niklas Langner for the Pierre Auger-Collaboration — III. Physics Institute A, RWTH Aachen

Measuring the mass composition of ultra-high energy cosmic rays (UHECRs) constitutes one of the biggest challenges in astroparticle physics. Nowadays, the most precise measurements can be obtained from measurements of the depth of maximum of air showers, $X_{\max}$, with the use of Fluorescence Detectors (FD), which can be operated only during clear and moonless nights.

With the advent of deep learning, it is now possible for the first time to perform an event-by-event reconstruction of $X_{\max}$ using the Surface Detector (SD) of the Pierre Auger Observatory. Therefore, previously recorded data can be analyzed for information on $X_{\max}$, and thus the cosmic-ray composition. Since the SD features a duty cycle of nearly 100%, the gain in statistics is a factor of 15 for energies above $10^{19.5}$ eV compared to the FD.

This contribution introduces the neural network specifically designed for the SD of the Pierre Auger Observatory. We evaluate its performance using three different hadronic interaction models and verify its functionality using Auger hybrid measurements. Finally, we quantify the expected systematic uncertainties and determine the UHECR mass composition using the first two moments of the $X_{\max}$ distributions up to the highest energies.

AKPIK 4.7 Thu 17:45 AKPIK-H13

Graph Neural Networks for Low Energy Neutrino Reconstruction at IceCube — •Rasmus Ørsøe — Trøjborggade 6, 3.sal, 1757 Copenhagen

A presentation on the application of graph neural networks for low energy neutrino reconstruction of IceCube events. Comparisons with current methods will be shown. Brief introduction to graph neural networks and motivation is included.

AKPIK 4.8 Thu 18:00 AKPIK-H13

Event-by-event estimation of high-level observables with data taken by the Surface Detector of the Pierre Auger Observatory using deep neural networks — •Steffen Hahn[1], Markus Roth[1], Darko Veberic[1], David Schmidt[1], Ralph Engel[1], and Brian Wundheiler[2] — [1]KIT, IAP, Germany — [2]UNSAM, ITEDA, Argentina

Probing physics beyond the scales of human-made accelerators with cosmic rays requires accurate estimation of high-level observables, such as the energy of the primary particle or the maximum of the shower depth. Measurements of the shower cascade, however, consist mainly of various, hard-to-interpret time signals which potentially contain non-trivial correlations. Deep neural networks are a convenient way to tackle such a problem in a general way.

The shower footprint measured by the surface detector of the Pierre Auger Observatory provides us with time slices of the ground signal of a shower cascade. This gives us an ideal test bed to determine the quality of network based reconstruction methods compared to that of regular analysis methods. However, a caveat of this approach is that the networks must be trained on Monte-Carlo simulations. Since present hadronic interaction models for energies beyond 10 EeV are extrapolations there are discrepancies between simulations and real data for which we have to correct for.

Here, we present a multi-purpose architecture and correction-method to predict high-level observables on measured data as well as physics results.

AKPIK 4.9 Thu 18:15 AKPIK-H13

Reconstruction of primary particle energy from data taken by the Surface Detector of the Pierre Auger Observatory using deep neural networks — Ralf Engel, Markus Roth, Darko Veberic, David Schmidt, Steffen Hahn, and •Fiona Ellwanger for the Pierre Auger-Collaboration — Karlsruhe Institute of Technology (IAP), Karlsruhe, Germany

To probe physics beyond the scales of human-made accelerators with cosmic rays demands an accurate knowledge of their energy. Indirect, ground-based experiments reconstruct this primary particle energy from measurements of the emitted fluorescence light or the time-signal of the shower footprint. Using fluorescence detectors, one is able to estimate former with good accuracy. These, however, exhibit a rather low duty cycle.

At the Pierre Auger Observatory the shower footprint is measured by a regular triangular grid of water-Cherenkov detectors. Since the shower development is a very intricate process the time signals of the detectors are fairly complex. Additionally, the sheer amount of data makes it non-trivial to find hidden patterns in their spatial and temporal distributions. Neural networks provide a straightforward way of tackling such a problem doing a data-driven analysis.

With large simulation data sets we are able to train more complex networks. Systematic differences between simulations and measured data require special attention to possible biases, which are quantified. In this work, we present a neural network architecture that gives an estimate on the energy for real data.