AKPIK 2: AKPIK II: Deep Learning

Time: Wednesday 16:00–18:15 Location: AKPIKa

AKPIK 2.1 Wed 16:00 AKPIKa

Demonstrating learned tree reconstruction with graph neural networks — James Kahn[2], Oskar Taubert[2], •Ilias Tsaklidis[1], Markus Götz[2], Giulio Dujany[3], Tobias Boeckh[1], Florian Bernlochner[1], Pablo Goldenzweig[2], Isabelle Ripp-Baudot[3], Lea Reuter[2], and Arthur Thaller[3] for the Belle II-Collaboration — [1]Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn — [2]Karlsruher Institut für Technologie (KIT) — [3]Hubert Curien Multi-disciplinary Institute, Strasbourg (IPHC)

Hierarchical tree data structures are commonly used in a variety of domains to express chronological interactions. Within particle physics, decay trees need to be reconstructed using only information from the final state particles (FSPs) that reach the detector. The FSPs are represented as leaf nodes in a decay tree graph and they are used to reconstruct the intermediate nodes up to the level of the root. Established methods that retrieve the structural information of the tree, often require domain-specific knowledge to narrow down the combinatorial phasespace, mainly due to the combinatorial explosion in scenarios with many FSPs. In this work, inspired by the usage of a tagging algorithm for full event reconstruction in Belle II, we propose a method of encoding the whole tree structure into leaf-node relations, using a Lowest Common Ancestor based matrix representation. We demonstrate this method using an attention-based transformer network as baseline and a Neural Relational Inference graph network.

AKPIK 2.2 Wed 16:15 AKPIKa

Deep Learning Based Analysis Approaches in Radio Interferometry — •Kevin Schmidt, Felix Geyer, Stefan Fröse, and Paul-Simon Blomenkamp — TU Dortmund, Dortmund, Germany

Radio interferometry enables studying our universe at the highest resolutions. The used telescope arrays collect information about the observed sky in Fourier space. Analyzing the measured sample allows the reconstruction of the source images. As the amount of available antennas in a radio interferometer array is limited, the measured Fourier space always remains incomplete. By directly applying the inverse Fourier transformation to the measured data sample, noisy artifacts dominate the reconstructed image.

The `radionets` project aims to reconstruct the incomplete data samples with Deep Learning based analysis approaches. To train Deep Learning models, suitable Monte Carlo data sets with known ground truths are essential. Therefore, a procedure to simulate observations of radio galaxies with radio interferometers is implemented. This talk gives an overview of the developed simulation chain and the general reconstruction idea.

AKPIK 2.3 Wed 16:30 AKPIKa

Deep Learning based Likelihood Reconstruction of IACT Events — •Noah Biederbeck — TU Dortmund

The Cherenkov Telescope Array (CTA) is the next-generation gammaray observatory, currently under construction. Once finished, it will comprise over 100 imaging air Cherenkov telescopes (IACTs) at two sites with the goal of improving over the sensitivity of the current generation by at least an order of magnitude. First prototypes for all telescope variants have achieved first light and are observing.

In this talk a novel approach to event reconstruction for IACT data, based on deep learning, is presented. A generative neural net predicts full camera images from a set of physical event parameters. These predicted images are compared to data using a Poissonian likelihood loss in order to reconstruct the event properties.

First results on single-telescope events will be presented and possible extensions to joint predictions of array events will be outlined.

AKPIK 2.4 Wed 16:45 AKPIKa

Boosting neural network performance through symmetry considerations using surface detector data from the Pierre Auger Observatory — Darko Veberic[1], David Schmidt[1], Markus Roth[1], •Steffen Hahn[1], Ralph Engel[1], and Brian Wundheiler[2] for the Pierre Auger-Collaboration — [1]Karlsruhe Institute of Technology (KIT), IAP, Germany — [2]Universidad Nacional de San Martin (UNSAM), ITEDA, Argentina

man-made accelerators ($\sim 10^{19}$ eV) is the detection and understanding of cosmic rays arriving at Earth. To probe them we rely solely on indirect detection of air showers. The hugest detector in this field of research is the Pierre Auger Observatory. On part of its detection strategy is to gauge the footprint of arriving particles at ground level with an triangular grid of multi-detector stations.

These surface detectors measure complex time signals giving us spatial and time information of the incoming secondary particles. This provides us with an huge amount of interpretable data which might contain hidden and convoluted knowledge not found by physical insights. Hence, exploiting deep neural networks for a data-driven analysis is a adequate way to explore this data even further.

Using symmetry considerations and modifying our input data accordingly, we are able to boost the performance of these networks without changing the networks'architectures or training process giving us basically a free improvement of prediction quality. Additionally, this standardization procedure also maximizes the information density in inputs allowing us to work memory-efficient.

AKPIK 2.5 Wed 17:00 AKPIKa

Belle II pixeldetector cluster analyses using neural network algorithms — •Stephanie Käs, Jens Sören Lange, Katharina Dort, Marvin Peter, Irina Heinz, Johannes Bilk, Peter Lehnhardt, and Johannes Budak — Justus-Liebigig-University

The Belle II DEPFET pixeldetector is operating since 2019, presently with 4 M pixels and trigger rates up to 5 kHz. The pixeldetector has the unique ability to detect exotic highly ionizing particles such as antideuterons or stable tetraquarks which due to their high energy loss do not reach the outer sub-detectors, and thus generate no reconstructable track. In order to identify these highly ionizing particles, multivariate analyses of pixeldetector clusters is performed. The multidimensional input space consists of variables such as single pixel signals, cluster observables, or Zernicke moments.

We present results for cluster classification using different neural network algorithms: multilayer perceptrons, Convolutional networks, Kohonen-type networks (often denoted as self-organizing maps) and Hopfield-type networks (often denoted as associate memories). Data preprocessing by Principal Components analysis and possible implementation on an FPGA for online reconstruction are discussed as well.

AKPIK 2.6 Wed 17:15 AKPIKa

Event reconstruction in JUNO-TAO using Deep Learning — •Vidhya Thara Hariharan — Institute for Experimental Physics, University of Hamburg

The primary goal of JUNO is to resolve the neutrino mass hierarchy using precision spectral measurements of reactor antineutrino oscillations. To achieve this goal a precise knowledge of the unoscillated reactor spectrum is required in order to constrain its fine structure. To account for this, TAO (Taishan Antineutrino Observatory), a tonlevel, high energy resolution liquid scintillator detector with a baseline of about 30 m, is set up as a reference detector to JUNO. The 20% increase in the coverage of photosensors, the installation of Silicon Photomultipliers (SiPMs) instead of PMTs, the smaller dimension and the low temperature at -51°C, would enable TAO to achieve a photoelectron yield of 4500 p.e./MeV as compared to 1200 p.e./MeV in JUNO. This would in turn help TAO to achieve an energy resolution of 1.5/E(MeV). The measurement of the reactor antineutrino spectrum with this energy resolution will provide a model-independent reference spectrum for JUNO.

The reconstruction can be performed using several approaches. However previous studies have proved Deep Learning yields competitive reconstruction results. Hence this work aims at demonstrating the general applicability of Graph neural networks (GNNs) to reconstruct vertex and energy and later at studying the directionality.

AKPIK 2.7 Wed 17:30 AKPIKa

Kinematic Analysis of Radio Jets with Deep Learning — •Paul-Simon Blomenkamp and Kevin Schmidt — TU Dortmund, Dortmund, Deutschland

Active galactic nuclei (AGN) are some of the most intensely studied objects in the night sky. Some of these AGNs can accelerate matter in their core to relativistic speeds. These jets are prominent sources in radio astronomy. Analysing the kinematic properties of radio jets can give insight on many physical properties of the host galaxy. Previously this analysis was mostly done by manually tracking Gaussian components of the jets, which by its nature involves some degree of arbitrariness.

This work aims at the automated detection of Gaussian components in radio jets with Deep Learning. This is expected to accelerate and improve on the manual methods. Ideally, the model will be able to independently identify the components and their position in order to perform a kinematic analysis. To achieve these aims a Deep Learning model using Convolutional Neural Networks is to be developed. The current results have been achieved by using object detection models. The used dataset is composed of simulated Gaussian jet components in 640×640 images and is labelled. At the current state, the model is able to confidently identify and locate all the Gaussian components within the image.

AKPIK 2.8 Wed 17:45 AKPIKa

A Neural Network Architecture for Radio Imaging — •Stefan Fröse and Kevin Schmidt — TU Dortmund, Dortmund, Deutschland

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 missing information in the uv-plane will be reconstructed using a Neural Network. The architecture of this network is similar to the architecture used for the task of superresolution. Superresolution is an approach for upscaling images from a low resolution to a high resolution. This method is transferred to the task of measuring a source in the Fourier space and filling in the missing information. The core of this architecture is a residual approach to the network. This can be written as $y = \mathcal{F}(x) + x$ with the set of measurements x, the set of complete information y and the mapping function $\mathcal{F}(x)$. The task of the network is to learn the underlying mapping function. The neural network is able to learn the correct mapping for simulated radio images and also shows convergence for more complex images with large- and small-scale structures.

AKPIK 2.9 Wed 18:00 AKPIKa

Evaluation of Interferometric Data Reconstructed by Neural Networks — •Felix Geyer and Kevin Schmidt — TU Dortmund, Dortmund, Deutschland

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 inference and 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.

A new and fast approach to reconstruct missing data reasonably is using Neural Networks. In this talk, the results and evaluation methods obtained using the simulations created in the `radionets` framework are presented and discussed. Especially the performance of clean versus noisy input data is examined.