AKPIK 2: Machine-learning methods and computing in particle physics

Zeit: Dienstag 16:00–17:50 Raum: H10

AKPIK 2.1 Di 16:00 H10

Pixel detector background simulation using generative adversarial networks at Belle II — •Matej Srebre — Ludwig-Maximilians-Universität München

The Pixel Vertex Detector (PXD) is an essential part of the Belle II experiment, allowing us to determinate the location of particle trajectories and decay vertices. The combined data from multiple detector subsystems along with PXD information is crucial in the event reconstruction phase to determine particle types, their tracks, and the decay chain. To model the effect of unwanted background noise on the track reconstruction in simulation we add simulated or recorded background data to the simulated detector signals from the generated physics process of interest. A large batch of statistically independent samples of background noise is required to not be biased by statistical fluctuations in the background data. The data from the PXD, however, is high in volume and requires a substantial amount of storage and bandwidth. As an efficient way of producing background noise we explore the idea of an on-demand noise generator using Generative Adversarial Networks.

AKPIK 2.2 Di 16:10 H10

Photon position reconstruction using Machine Learning with the Belle II electromagnetic calorimeter — •Yu Hu — DESY Notkestraße 85 22607 Hamburg

The Belle II experiment at the SuperKEKB accelerator in Tsukuba, Japan is the successor to the B factory experiment Belle at KEKB. In 2018, the experiment completed its first run of commissioning collisions, and is currently preparing for physics data taking later in 2019. The electromagnetic calorimeter of the Belle II detector is mainly used to measure photons from the decays of B mesons. This talk will describe a new neural networks based photon position reconstruction algorithm. This can improve the photon position resolution, the photon position bias, and has an impact on the reconstruction of pi0 decays.

AKPIK 2.3 Di 16:20 H10

Analysis of GERDA detector surface events with deep learning algorithms — •Péter Kicsiny for the GERDA-Collaboration — Max-Planck-Institut für Physik, München, Deutschland

The Gerda experiment searches for the neutrinoless double beta ($0\nu\beta\beta$) decay of the ^{76}Ge in high purity germanium detectors enriched in this isotope. The detectors are operated in liquid argon. A primary background source around the Q-value of the $0\nu\beta\beta$ decay ($Q_{\beta\beta} = 2039$ keV) are β-decays of ^{42}K resulting from the contamination of natural argon with the isotope ^{42}Ar. The β-particles from the decay deposit their energy close to the detector surface. The rejection of these events is currently performed by a one parameter cut based on the current pulse amplitude divided by the total energy. In order to identify surface β-events separated from Compton scattered γ-events, more sophisticated methods are investigated. Artificial neural networks with advanced deep learning architectures are becoming more efficient in such classification tasks. Preliminary results on surface event classification using deep learning algorithms will be discussed using training data from ^{39}Ar β-decays present in the background spectrum at low energies ($Q_\beta = 565$ keV).

AKPIK 2.4 Di 16:30 H10

Learning to rank Higgs-Boson candidates — •Lukas Pensel, Alexander Segner, Marius Köppel, Martin Wagener, Andreas Karwath, Christian Schmitt, and Stefan Kramer — Johannes Gutenberg University Mainz, Germany

The Higgs boson was discovered in July 2012 and the Nobel prize was awarded for its theoretical prediction of this boson subsequently in 2013. The current research focus is now on the precise measurement of the Higgs boson couplings and the search for possible deviations from the predictions by the standard model of particle physics in as many production and decay channels as possible. One of the interesting channels is the production of the Higgs Boson via vector boson fusion, with subsequent decay $H \to WW^* \to l\nu l\nu$. Since this channel, as well as many others, is limited by large background contributions, in this case dileptonic $t\bar{t}$ decays, maximizing the signal to background ratio is a crucial step in these analyses. Commonly, machine learning models using boosted decision trees and standard neural networks are trained to differentiate these signals from background. Machine learning approaches can also be employed for ranking problems aiming to sort a list according to the relevance labels of its elements. This can be done by pairwise comparison of all instances in the list. Recently, neuronal networks have been used for this task as well. Here, we present a method using such a pairwise approach from the field of *learning to rank* combined with neuronal networks to sort a list of Higgs-events, depending on their relevance class, into signal and background.

AKPIK 2.5 Di 16:40 H10

Refining the EXO-200 detector simulation using GANs — •Federico Bontempo, Johannes Link, Tobias Ziegler, Gisela Anton, and Thilo Michel — Friedrich-Alexander-Universität Erlangen-Nürnberg, ECAP

The EXO-200 experiment searches for the neutrinoless double beta ($0\nu\beta\beta$) decay of ^{136}Xe with a single-phase liquid xenon (LXe) time projection chamber (TPC) filled with enriched LXe. The TPC provides the deposited energy of events in LXe together with their 3D position. A GEANT4 Monte Carlo (MC) simulation is used to model the physics interactions and the resulting detector response. These simulations are crucial for most physics analyses. In this study, we apply Deep Learning methods, esp. Generative Adversarial Networks (GAN), to improve the MC simulations by reducing potential imprecisions compared to measurements. Improvements pave the way for applying other Deep Learning based methods that rely on an accurate detector modelling.

AKPIK 2.6 Di 16:50 H10

Event reconstruction in EXO-200 using Deep Learning — •Johannes Link, Federico Bontempo, Tobias Ziegler, Gisela Anton, and Thilo Michel — Friedrich-Alexander-Universität Erlangen-Nürnberg, ECAP

The EXO-200 experiment searches for the neutrinoless double beta decay ($0\nu\beta\beta$) of ^{136}Xe using a time projection chamber (TPC) filled with enriched liquid xenon. An event taking place in the TPC leads to secondary electrons and scintillation light. The electrons drift in an electric field, where in the first plane of wires the induction signal and in the second plane of wires the collection signal is measured. In this contribution, we present an alternative approach of event reconstruction using Deep Learning methods, e.g. Convolutional Neural Networks (CNN). Raw collection and induction wire signals are used to reconstruct the energy and the position of events in the EXO-200 detector. We compare the performance of the Machine Learning approach to the conventional reconstruction in EXO-200.

AKPIK 2.7 Di 17:00 H10

Circuit Synthesis of the Kuramoto Model and Electrical Interpretation of its Synchronization Condition — Karlheinz Ochs[1], •Dennis Michaelis[1], Julian Roggendorf[1], Petro Feketa[2], Alexander Schaum[2], and Thomas Meurerer[2] — [1]Ruhr-University Bochum, Bochum, Germany — [2]Christian-Albrechts-Universität zu Kiel, Kiel, Germany

The authors present a circuit synthesis of the well-known Kuramoto model. It is a fundamental setup which consists of non-linearly coupled oscillators, making it an interesting subject in the context of synchronization. The circuit synthesis consists of synthesizing the oscillators first and then deriving a circuit of a general resistive interconnection network. Additionally, the standard Kuramoto model implies a strongly connected interconnection network which we generalize to an arbitrary connection topology. Based on the resulting electrical circuit, a sufficient synchronization condition is derived that coincides with the system-theoretic synchronization condition that is known from the literature. By interpreting the electrical quantities, simulation results explain in detail how the different kinds of synchronization known to be present in the Kuramoto model (zero-sum, anti-phase, complete synchronization) can occur. A simulation scenario focuses on an auxiliary oscillator aiding the transition from an anti-phase configuration to a state of complete synchronization. The structured approach of the synthesis and its electrical interpretation is seen as a general procedure to derive perspectives on neural networks, which typically require circuits for reasons of efficiency, low costs and high speed.

AKPIK 2.8 Di 17:10 H10

HfO_2-based Memristive Navigation Processor — Karlheinz Ochs, •Enver Solan, Dennis Michaelis, and Leonard Hilgers — Ruhr-University Bochum, Bochum, Germany

Mathematically complex optimization problems are historically interesting subjects of research. That is because convergence time of such problems does not scale well with the complexity. One of these problems is the np-hard navigations process problem, where the shortest path between an entry and an exit in a maze is desired. Electrical circuits are proper tools to solve this problem efficiently and the reasons are twofold. First, a current naturally chooses the path of least resistance in any given circuit, which is a desirable feature in this context. Second, electrical circuits are inherently massively parallel which lead to fast convergence times. To this end, a self-organizing electrical circuit with HfO_2-based resistive random access memory-cells (RRAM-cells) is proposed that obtains a solution within a convergence time that is linearly proportional to the length of the shortest path. RRAM-cells are known to have a fast switching behavior which is favorable for quick convergence. All necessary details on how to construct an arbitrarily sized maze and what occurs in the switching process of the RRAM-cells to obtain the optimal solution are presented. The authors also propose an emulator of the electrical circuit based on the wave digital method which could be implemented in embedded systems, e.g. digital signal processors or field programmable gate arrays. Different simulation scenarios confirm the previously derived theoretical results.

AKPIK 2.9 Di 17:20 H10

Universal Self-Organizing Logic Gates: A Wave Digital Emulation — Karlheinz Ochs, •Enver Solan, Dennis Michaelis, and Leon Schmitz — Ruhr-University Bochum, Bochum, Germany

Self-organizing logic gates are logic gates that can be operated in 'reverse' mode, meaning that every node can electively used as input or output node. This property can be exploited in the context of cryptographic methods, which rely on one-way functions. A commonly deployed one-way function in today's cryptographic approaches is the prime factorization where it is easy to check whether a given prime factorization results in a certain number, but it is difficult to obtain the prime factorization of a given number. In this work, the authors show a general electrical circuit with multiple memristors that can function as either a self-organzing or-gate or and-gate. It is known that it is possible to construct any logical conjunction with these two gates. The authors then exploit the wave digital method, which is known to preserve stability, to obtain a highly flexible emulator of the electrical circuit that for example could be implemented on a digital signal processor. This enables live parameter optimization and sensitivity analyses, making it a powerful tool to investigate different physical memristor models in this application. The simulation results verify a proper functioning of the emulator.

AKPIK 2.10 Di 17:30 H10

Solving the Np-complete Subset Sum Problem with an Electrical Circuit Using Physical Memristor Models — Karlheinz Ochs, Enver Solan, •Dennis Michaelis, and Maximilian Herbrechter — Ruhr-University Bochum, Bochum, Germany

Logic gates are the building blocks to set up any logical conjunction. To do so, they have predetermined input and output nodes. Subject to current research are self-organizing (SO) logic gates which can be operated 'backwards', meaning that the role of input and output nodes can be reversed. With this functionality, mathematically complex problems, such as np-hard or even np-complete problems, can potentially be solved efficiently. Such problems are utilized for cryptographic systems, where many of today's encryption techniques are based on the np-hard prime factorization. In the upcoming times of quantum computing, more sophisticated encryption techniques are required. One of the proposed methods for post-quantum systems in the literature is based on the np-complete subset sum problem. In this work, we show an electrical circuit that deploys models of real memristors to solve the subset sum problem for three 3-bit numbers. To this end, we utilize SO half- and full-adders, which consist of SO and- and xor-gates with HfO_2-based resistive random access memory cells. These devices are known to have rapid switching behavior, making them a suitable choice for solving complex optimization problems in a short amount of time. This could indicate that methods based on the subset sum-problem might not be sufficient to ensure proper encryption of data since memcomputing techniques exist to solve this problem efficiently.

AKPIK 2.11 Di 17:40 H10

Was ist Geometrische Algebra? Auf dem Weg zu einer modernen Mathematikausbildung in der Ingenieurinformatik — •Martin Erik Horn — Hochschule für Technik und Wirtschaft Berlin

Konforme geometrische Strukturen werden in der Informatik zur Animation, zur Simulation, zur Mustererkennung sowie in der Robotik zur Steuerung von Bewegungsabläufen und in zahlreichen weiteren Bereichen eingesetzt. Die Mathematik konformer geometrischer Strukturen sollte deshalb auch elementarer Bestandteil der Informatikausbildung sein.

Diese mathematische Richtung kann – beispielsweise auf der Grundlage von Ansätzen wie www.phydid.de/index.php/phydid-b/article/view/550 – physikalisch fundiert werden. Im Vortrag wird dieser Ansatz vorgestellt und gezeigt, wie die Geometrische Algebra unter Rückgriff auf physikalische Erklärungsmuster der Pauli- und Dirac-Algebra in einem Mathematikkurs des Bachelor-Studiengangs Ingenieurinformatik eingeführt und diskutiert wurde.