T 69: DAQ and Trigger 3

Time: Wednesday 16:15–18:30 Location: T-H28

T 69.1 Wed 16:15 T-H28

Development of an FPGA Implementation of Convolutional Neural Networks for Signal Processing for the Liquid-Argon Calorimeter at ATLAS — Anne-Sophie Berthold, •Nick Fritzsche, Markus Helbig, Rainer Hentges, Arno Straessner, and Johann Christoph Voigt — Institut für Kern- und Teilchenphysik (IKTP), TU Dresden, Germany

The Phase-II upgrade of the ATLAS detector will prepare for the high-luminosity phase of the LHC, where the number of proton-proton collisions occurring at the same time will increase significantly. This leads to higher requirements for the data processing, since the rate of detected particles in one detector cell will increase. New machine learning solutions are under development to better reconstruct the energy deposited in the calorimeter and its timing information than the current optimal filter approach.

This talk introduces the implementation of convolutional neural networks for FPGA hardware. The application of time division multiplexing is discussed, which is necessary to cover the high number of detector readout channels and to reuse the network for multiple input streams. The latest performance results in terms of FPGA resource usage, achievable operation frequency and latency are presented. To verify the hardware implementation, a software reference model was created and the precision of the calculation results was analyzed. At last, first preparations for tests on hardware are shown.

T 69.2 Wed 16:30 T-H28

Towards the next generation Level-1 Trigger of SuperCDMS — •Hanno Meyer zu Theenhausen — Karlsruher Institut für Technologie

The SuperCDMS SNOLAB dark matter search experiment targets sensitivity towards nuclear and electron recoils down to energies of a few eV. At the lowest energies, the detector sensitivity is limited by thermal and electronic noise. To extract signals from the noise with high efficiency and resolution, SuperCDMS employs a Level-1 trigger system implemented on an FPGA on custom-hardware detector readout cards. Therein, digitized input traces are analyzed in a complex trigger architecture with a finite-impulse-response (FIR) filter at its heart. The FIR is configured as an optimal filter (OF) which can cause pathological "echo triggers" in the presence of large pulses. This presentation reports on the Level-1 trigger architecture, the OF FIR design and how echo triggers are circumvented making use of the complex trigger logic. Furthermore, an outlook on the performance of a neural network trigger as a potential trigger upgrade is given.

T 69.3 Wed 16:45 T-H28

The ATLAS Forward Feature Extractor for the Phase-II trigger upgrade — •Adrian Alvarez Fernandez, Julian Blumenthal, Stefan Tapprogge, Ulrich Schaefer, and Bruno Bauss — Institut für Physik, Johannes Gutenberg Universität

The ATLAS detector will undergo many upgrades to account for the more challenging running conditions of the High Luminosity LHC. Some of these Phase-II upgrades will be focused on improving the trigger system, a crucial part to deal with the higher data rates and pile-up. Phase-I upgrades for Run 3 introduced the Feature EXtractors for a more refined processing of the calorimeter information and to better discriminate between jets, photons, electrons and taus. A Forward Feature EXtractor (fFEX) will be developed for the HL-LHC that will provide more flexible algorithms for the objects in the forward region ($|\eta|>2.5$ for electrons and photons and $|\eta|>3.2$ for jets). In contrast to the first level calorimeter trigger before HL-LHC, this new system will have access to the full detailed calorimeter granularity. The status of the preliminary design work on the fFEX will be presented and possible technology options will be discussed.

T 69.4 Wed 17:00 T-H28

Neural network based primary vertex reconstruction with FPGAs for the upgrade of the CMS level-1 trigger system — •Matthias Komm — Desy, Hamburg

A major challenge of the high-luminosity upgrade of the CERN LHC is to single out the primary interaction vertex of the hard scattering process from the expected 200 pileup interactions that will occur each bunch crossing. To meet this challenge, the upgrade of the CMS experiment comprises a complete replacement of the silicon tracker that will allow for the first time to perform the reconstruction of charged particle tracks and the primary interaction vertex at the hardware-based first level of the event trigger system (L1). Knowledge of the primary interaction vertex is a central component for distinguishing tracks and calorimeter clusters belonging to the hard scattering process from pileup interactions, which subsequently improves the energy estimate and resolution of physics objects such as jets and the missing transverse momentum. This talk will focus on the reconstruction of the primary vertex from tracks at L1 within the stringent time requirements of O(100ns) while being additionally restricted by the FPGA resource usage and latency. To optimally exploit and pass-on the available information at each stage of the vertex reconstruction, an algorithm based on an neural network model has been developed that possesses simultaneous knowledge about all stages and hence enables end-to-end optimization. Future plans for operating and tuning the algorithm on real data during data-taking will also be outlined.

T 69.5 Wed 17:15 T-H28

Development of machine-learning based topological selection algorithms for the upgraded L1 trigger system of the CMS detector — •Ihor Komarov, Johannes Haller, Finn Labe, Artur Lobanov, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

Future data-taking periods at the LHC bring a major increase of the instantaneous luminosity. To cope with the large detector occupancy within the bandwidth constraints, significant improvements of the trigger systems of the experiments are needed. The upgraded Level-1 trigger system of the CMS experiment will allow the execution of complex algorithms, such as neural networks, on field-programmable gate arrays (FPGAs).

In this talk, a first proof-of-concept study on fast neural-network-based selection algorithms for the L1 trigger system of CMS will be presented. The algorithms were benchmarked with top-quark and Higgs pair production signals. Preliminary results show significant performance improvements compared to existing algorithms.

T 69.6 Wed 17:30 T-H28

Anomaly detection as a new strategy for the CMS Trigger — •Sven Bollweg, Karim El Morabit, Gregor Kasieczka, and Artur Lobanov — University of Hamburg, Germany

There exist strong hints for the existence of physics beyond the standard model (BSM). To search for such BSM processes at the LHC, potential candidate events first need to be selected. At CMS, the first selection step is the Level 1 (L1) trigger, which decides whether an event is stored for further analysis. The trigger decision is usually based on criteria motivated by specific models. Another strategy uses the idea that BSM events differ from events originating from standard model (SM) processes. A trigger decision could then utilize this difference to detect anomalous event properties.

This talk discusses such an anomaly detection trigger based on neural networks. An autoencoder (AE) network is trained to reproduce SM events. Using the AE to reproduce BSM events with anomalous properties leads to a reduced quality which can be used for the trigger decision. Since the L1 trigger has a very limited time for the decision, the AE needs to be deployed on dedicated hardware in the form of field programmable gate arrays which presents additional challenges.

T 69.7 Wed 17:45 T-H28

Implementation of tracking algorithms for live reconstruction using AI processors — •Patrick Schwäbig[1], Jochen Kaminski[1], Michael Lupberger[1], Klaus Desch[1], and Stephen Neuendorffer[2] — [1]Physikalisches Institut, Universität Bonn, Deutschland — [2]Xilinx Research Labs, San Jose, USA

For years, data rates generated by modern detectors and the corresponding readout electronics exceeded by far the limits of bandwidth and data storage space available in many experiments. Using fast triggers to discard uninteresting and irrelevant events is a solution used to this day. FPGAs, ASICs or even directly the readout chip are programmed or designed to apply a fixed set of rules based on low level parameters for an event pre-selection.

Up until the last few years, live track reconstruction for triggering

was rarely possible due to a conflict between processing time and the required trigger latency. With the emergence of novel fast and highly parallelized processors, targeted mainly at AI inference, attempts to sufficiently accelerate tracking algorithms become viable. The Xilinx Versal AI Series Adaptive Compute Acceleration Platform (ACAP) is one such technology and combines traditional FPGA and CPU resources with dedicated AI cores and a network on chip for fast memory access.

In this talk AI and non-AI algorithms for track reconstruction and especially their implementation on the Xilinx VCK190/Versal VC1902 Evaluation Kit for a dark photon experiment at the ELSA accelerator in Bonn will be shown and the expected performance will be discussed.

T 69.8 Wed 18:00 T-H28

A Hardware-Based Track Trigger — •Joachim Zinsser, Sebastian Dittmeier, and André Schöning — Physikalisches Institut, Universität Heidelberg

A hardware-based solution to filter interesting events more efficiently was explored for the planned increase in luminosity during the ATLAS Phase-II Upgrade. The plan is to install a filter based on the particles' tracks, which have to be evaluated in real-time. This task is well suited for implementation in hardware since, on the one hand, it requires only basic arithmetics and comparisons, and, on the other hand, it can be implemented in highly parallel hardware architecture, e.g., by exploiting FPGAs. This approach utilizes linear approximations to the helix parameters of trajectories and a database of simulated possible trajectories. A Track Fitter is implemented on the Stratix X FPGA from Intel with an integrated High Bandwidth Memory (HBM) for storing the simulated constants. In this talk, the final state of the firmware will be discussed and the implementation in hardware will be compared to simulation results and expectancies.

T 69.9 Wed 18:15 T-H28

Jet Tagging in the Level-1 Trigger of CMS for the HL-LHC — •Philipp Rincke, Karim El Morabit, Gregor Kasieczka, and Artur Lobanov — Institut für Experimentalphysik, Universität Hamburg

With the upcoming upgrade of the High-Luminosity LHC, triggering in the CMS experiment will become more challenging as more particles will be present in each event. A possible solution to the increased complexity could be to employ trigger algorithms that use inputs from all sub-detectors that will become available in future upgrades and the increased computing power of the FPGAs on which the algorithms of the Level-1 Trigger (L1T), the first trigger level in CMS, are implemented.

At the L1T track parameters and particle identification of some of the jet constituents will be available, making it possible to evaluate the jet substructure. Many high-energy physics analyses require jet flavour identification, for which the substructure information can be exploited. By attempting this in the L1T a higher fraction of interesting events could be recorded or thresholds could be lowered. One big challenge is that neural networks, often used in jet tagging, are not straightforward to deploy on FPGAs.

Besides the tagging performance, strict timing and resource limitations need to be considered, which results in a compromise between network architecture and size. In this talk we present studies on how jet tagging can be used in the L1T. We consider a simple multilayer perceptron architecture as well as graph-inspired network architectures.