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Navigation, field integration and track parameter transport through detectors using GPUs and CPUs within the ACTS R&D project

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The use of hardware acceleration, particularly of GPGPUs is one promising strategy for coping with the computing demands in the upcoming high luminosity era of the LHC and beyond. Track reconstruction, in particular, suffers from exploding combinatorics and thus could greatly profit from the massively parallel nature of GPGPUs and other accelerators. However, classical pattern recognition algorithms and their current implementations, albeit very successfully deployed in the CPU based software of current LHC experiments, show several shortcomings when adapted to modern accelerator architectures; the geometry, for example, is often characterized by runtime-polymorphic shapes, which are incompatible with common heterogeneous programming platforms. In addition, field integration modules need efficient access to the magnetic field on a variety of devices, and adaptive Runge-Kutta methods may cause thread divergence.

In order to investigate whether state-of-the-art CPU based track reconstruction software can be adapted to run efficiently on GPUs, the ACTS project has launched a dedicated R&D program aiming to develop a demonstrator that mirrors the current track reconstruction chain based on seed finding followed by a combinatorial Kalman filter available in the ACTS suite. We demonstrate the implementation and performance of a core component of this chain: the propagation of track parameters and their associated covariances through a non-homogenous magnetic field including the navigation through a highly complex geometry with different shapes together with the application of material effects when passing through detector material. This demonstrator showcases the usage of the detray library for geometry description and navigation, the covfie library for an efficient description and interpolation of a complex magnetic field on different hardware backends, a dedicated algebra plugin that allows using different math implemenations, and is based on the vecmem library, which has been developed to handle memory resources on host and device. We demonstrate that it is possible to perform this task using single-source code across multiple devices, and we compare the performance of this heterogeneous reconstruction chain to existing CPU-based code in the ACTS project.

Significance

This is a major step in our R&D program to bring a realistic track reconstruction chain based on Combinatorial Kalman Filtering onto GPUs - it showcases the components that have been developed and partly presented at ACAT and other conferences in a real-world scenario.

References

The detray library has been presented in ACAT 2021:
https://indico.cern.ch/event/855454/contributions/4605075/

The vecmem library has been presented at ACAT 2021:
https://indico.cern.ch/event/855454/contributions/4605054

The newly developed covfie library will be submitted as a dedicated abstract to this conference, as it could serve a more broader scope (e.g. simulation).

Experiment context, if any

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