Accelerated charged-particle tracking for ATLAS trigger at the HL-LHC era

The High Luminosity Large Hadron Collider (HL-LHC) will be upgraded by 2030 to deliver a factor of 5 more collisions to the ATLAS experiment (as well as to other experiments) as compared to the current conditions. More collisions, translate directly to the increased potential of observing rare processes and to increase precision allowing for statistically significant tests of deviations from the well-known Standard Model of elementary particles. Examples of particular interest are Higgs boson self-coupling or searches of yet unknown particles predicted by new theories.

In order to look for very rare types of collisions a large number of them are produced. That number, translated to a data volume, is too large to be handled by modern information technologies. Fortunately most of them contain already well understood physics and can be rejected without the loss of scientific potential of the experiment. The filtering process takes place online and is very delicate. In the case of ATLAS about 0.0025% of data is retained. Within this small fraction of the data, the collisions of interest need to be retained with a high efficiency and almost no uninteresting ones kept. Complex hardware and software systems are used for this purpose. They are called triggers and the filtering process, triggering.

The collisions at the LHC occur in 25 nano second intervals when bunches of protons or ions cross each other in the center of the detector. The data related to one bunch crossing is seen by the detector as a whole as a so-called collision event. More LHC collisions provided by the LHC in the future means for detectors not only wealth of the data but also many challenges. First, the collision events of interest will happen more frequently and thus more data needs to be recorded. Secondly the data will be more complex. This is because, together with a collision of interest up to 200 parasitic ones will occur. To prepare for that ATLAS builds a high granularity charged particles inner tracking detector (ITk). Charged particle tracks registered by this detector will be essential to understand these complex collisions. They will also be needed online for the purpose of triggering. This information will facilitate selection of many specific signatures of in p-p collisions as well as for heavy-ion.

The process of reconstructing particle trajectories from detector signals is unfortunately very complex. Raw detector signals from the ITk, need to be first translated to positions and then combined into charged particle tracks. So far used algorithms are insufficiently fast to be applicable for triggering. Their evaluation time, a key parameter in online systems, scales very nonlinearly with the amount of data. Therefore the ATLAS collaboration decided to construct an auxiliary system dedicated solely for charged particle tracks reconstruction online. The necessary computation power will be provided by so-called computing accelerators like Field Programmable Gate Arrays or Graphical Processing Units. They offer better processing power/cost ratio. Algorithms used for charged particle tracking have to be redesigned, or reinvented to efficiently use this type of hardware. Necessary R & D is carried within the ATLAS Collaboration to find an optimal solution. It is a collaboration of about 20 universities and research laboratories already working within ATLAS.

The group at AGH University of Science and Technology in Kraków has been involved in this project since the beginning in 2021. Currently we are responsible for the organization of the software framework. However, the aim of group activity is development of novel algorithms and their implementation on specialized hardware. We bring to the project know-how on how to use emerging technologies allowing us to use relatively high level programming techniques for non CPU processing units thus facilitating their use. Solutions devised within this project will be first integrated with ACTS, a cross-experiment open-software package for charged particle tracking that is planned to be used by ongoing experiments and planned future experiments.