Faster matrix algebra for ATLAS

(Project Proposal by STFC Rutherford Appleton Laboratory in 2018,http://hepsoftwarefoundation.org/gsoc/2018/proposal_ATLASEigen.html)

Introduction

ATLAS is one of two general-purpose detectors at the Large Hadron Collider(LHC). It investigates a wide range of physics, from the search of Higgs boson particles to extra dimensions and particles that could make up the dark matter. Dark matter can be detected by the change in energy, momentum after the collision of the particles at LHC.

Beams of particles from the LHC collide at the center of the ATLAS detector which creates new particles, which fly out from the collision point in all directions. Six different detecting subsystems arranged in layers around the collision point record the paths, momentum, and energy of these particles, allowing them to be individually identified.

The interactions in the ATLAS detectors create an enormous flow of data. Complex data-acquisition and computing systems are then used to analyze the collision events recorded.

When the LHC is operating, 40 million packets of protons collide every second at the center of the ATLAS detector. Every time there is a collision, the ATLAS Trigger selects interesting collisions and writes them to disk for further analysis.

Background

To track these trajectory of charged particles and their collisions a large number of alignment parameters are required which can range from **10^4** to **10^5**. The alignment precision depends on the amount of data used in the alignment and it may be necessary to use millions of tracks. The amount of data and the number of parameters, with weakly defined or undefined degrees of freedom, represents a problem even for today's computers. Several alignment algorithms as well as heavy CPU sonsumption is used to optimize these parameters. One such method requires the solution of a system of linear equations. To store these equations the symmetric *n*-by-*n* matrix is used.Symmetric matrices make up a large fraction of the matrices used in track reconstruction. ATLAS Tracking Software makes heavy use of matrix algebra, implemented with the **Eigen** library. The CLHEP maths library was previously used throughout the ATLAS software, but after investigating potential alternatives, the decision was made to move to Eigen. Eigen was chosen since it offered the largest performance improvements for ATLAS.

Eigen is a C++ template library for linear algebra: matrices, vectors, numerical solvers, and related algorithms. It is a fast, robust, open source linear algebra library, used by e.g. the Google Tensorflow, Ceres Large Survey Synoptic Telescope projects as well as ATLAS.

Currently, Eigen does not have any macros or templates to store Symmetric Matrices. Due to which a huge amount of storage space is wasted in case of large data of particles.