Mid Term Project Report for Google Summer of Code 2022

Symplectic Integrators

Mentors

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Project Introduction:

The aim of this GSoC project is to implement Symplectic Integrators in the Geant4 Library. Symplectic Integrators can have a immense impact on tracking particles in electromagnetic fields as they conserve the phase space volume and energy. This important for applications that rely on precise measurement of energy and momentum of particles.

Current Status:

- **Learning to Use the Geant4 Repository:** The first step into developing code into geant4 was to learn to use geant4 itself. I used a variety of resources to do so. Geant4's official Application Development Guide was very useful during my initial learning phase. This was followed by some other resources that my mentors provided me. But perhaps, the most important bits were learned by asking questions!

  After learning the fundamentals, my first task was to build a Geant4 applications that tracks particles (electron, proton, geantino etc) in a magnetic field.This is to be used as a testing bed for the symplectic steppers that will be implemented.This involved creating a custom Dectector Constructor class to define the geometery and initialize a magnetic field as well as setting up and tracking steplength

and track length limit. I also created a PhysicsList to to define particles such as electron, protons charged geantino etc.Lastly I created a derivation from G4PrimaryGeneratorAction class to initialize the starting conditions of the tracking.

- **Identifying the First Method:** After finishing up the test bed, my next task to research and identify a suitable 2nd order symplectic method that would suite our needs. After careful thoughts and deliberation, we decided to go with the Boris Algorithm. The Boris Algorithm is not symplectic, but it does preserve phase space volume. It is also used in a variety of electromagnetic applications.Hence, it was an ideal candidate.

- **Implementing the Boris Algorithm:** In Geant4, any integration method is implemented by constructing a stepper and a driver. The stepper implements the actual scheme of the method whereas the driver handles other important aspect as such step length, error control etc.
  Along these lines, I implemented G4BorisScheme.hh and G4BorisScheme.cc that implement the stepper class for the Boris Algorithm.The G4BorisDriver class was also implemented and that functions as the driver class for G4BorisScheme.The following papers were used for the implementation:
  1.) A Comprehensive Comparison of Relativistic Particle Integrators
  2.) On the Boris solver in particle-in-cell simulation

The code corresponding to the above work can be found in the following Merge Request :MR!2930

Next On The Agenda:

I have the following task that will be needing implementation next:

1.) Thoroughly test the Boris method so that it becomes reliable and ready for use.
2.) Identify the next symplectic method of integration (of Order 4 or higher).
3.) Implement the aformentioned method into the codebase.