Accelerating the numerical simulation of magnetic field lines in tokamaks using the GPU

R.C. Kalling,[1] T.E. Evans,[1] D.M. Orlov,[2] D.P. Schissel,[1] R.Maingi,[3] J.E. Menard,[4] and S.A. Sabbagh[5]

[1]General Atomics, P.O. Box 85608, San Diego, CA, 92186-5608, USA
[2]University of California-San Diego, 9500 Gilman Drive, La Jolla, CA, 90093-0417, USA
[3]Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN, 37831, USA
[4]Princeton Plasma Physics Laboratory, P.O. Box 451, Princeton, NJ, 08543, USA
[5]Applied Physics and Math Department, Columbia University, 2960 Broadway, New York, NY, 10027-6902, USA

Abstract

TRIP3D is a field line simulation code that numerically integrates a set of nonlinear magnetic field line differential equations. The code is used to study properties of magnetic islands and stochastic or chaotic field line topologies that are important for designing non-axisymmetric magnetic perturbation coils for controlling plasma instabilities in future machines. The code is very computationally intensive and for large runs can take on the order of days to complete on a traditional single CPU. This work describes how the code was converted from Fortran to C and then restructured to take advantage of GPU computing using NVIDIA's CUDA. The reduction in computing time has been dramatic where runs that previously took days now take hours allowing a scale of problem to be examined that would previously not have been attempted. These gains have been accomplished without significant hardware expense. Performance, correctness, code flexibility, and implementation time have been analyzed to gauge the success and applicability of these methods when compared to the traditional multi-CPU approach.

Keywords: Stochastic magnetic field lines; Graphical processing unit; General-Purpose computation on Graphical Processing Units; Tokamaks; NSTX; Non-axisymmetric magnetic perturbations