TARGET
TArgeting Realistic GEometry in Tokamak code gysela

CEMRACS project 2016

Abstract

Some of the key issues to address realistic gyrokinetic simulations of Tokamaks are: efficient and robust numerical schemes, accurate geometric description, good parallelization algorithms, parallel scalability. In this project we intend to improve the parallel application Gysela, that uses a gyrokinetic model. To access realistic geometry and realistic physics, a new variant for the interpolation method will be implemented that can handle the mesh singularity in the poloidal plane at $r = 0$ (polar system is used for the moment in Gysela). Also, the gyroaverage operator based on *Hermite interpolation* method will be revised in order to cope with non-circular geometry.

Context

Understanding and control of turbulent transport in thermonuclear plasmas in magnetic confinement devices is a major goal. This aspect of first principle physics plays a key role in achieving the level of performance expected in fusion reactors. In the ITER design[1], the latter was estimated by extrapolating an empirical law. The simulation and understanding of the turbulent transport in Fusion plasmas remains therefore an ambitious endeavour.

The Fusion energy community has been engaged in high-performance computing (HPC) for a long time. Computer simulation is and will continue to be a key tool for investigating several aspects of Fusion energy technology, because right now there is no burning plasma experiments like ITER. Some of the key issues to address realistic simulations of the Tokamak are: efficient and robust numerical schemes, accurate geometric description, good parallelization algorithms, parallel scalability. The numerical models are often time-hungry and we then need large amount of computational time that are typically provided by advanced computational facilities. In order to design Tokamak simulation tools, we need to foster the involvement of physicists, applied mathematicians and computer scientists developing codes together.

Objectives

In Plasma physics, a *kinetic* model describes the particle velocity distribution function at each point in the plasma, no assumption is done *a priori* on the distribution along the velocity dimension. Another approach is *fluid* modeling, the plasma is described in terms of smoothed quantities (like density and averaged velocity around each position) and assumes a shape for the distribution in velocity space. This CEMRACS project targets to improve the parallel application Gysela, that uses a gyrokinetic model (*kinetic* description). Routinely, this code performs large simulations using from 1k to 16k cores.

During the CEMRACS project, we intend to work on the development of numerical methods to access realistic geometry and realistic physics. We will implement into the Gysela code a new approach that can circumvent two issues that we are facing now: a central hole near $r = 0$ exists because the semi-lagrangian method and the gyroaverage operator are difficult to use in polar coordinate system at this location. In particular, there are too much points along θ direction in the poloidal plane close to $r = 0$ (mesh singularity).

[1] http://www.itercad.org/

The project will focus on:

- **New variant for the interpolation method**. This will be investigated in the semi-Lagrangian solver to remove the central hole of the poloidal plane that is used in Gysela. This hole was introduced because of polar coordinate system and a singularity at $r = 0$. The new poloidal grid that we want to use is sketched in Fig 1. Compared to a polar coordinate system, this approach has: a variable number of grid points in θ direction depending on radial position r. The advection operator of Gysela will be changed to match the new poloidal grid. Nevertheless we do not intend to overhaul the whole application, other operators (collisions, heat sources, Poisson solver) will remain on the previous polar grid for the moment (which can be easily mapped onto the new grid).

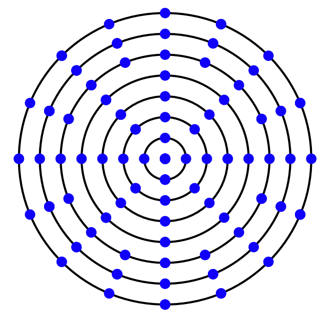

Figure 1: New poloidal grid targeted. The number of points in θ direction (angle) depends on the radial position (distance to the center).

- ***Gyroaverage* operator in complex geometry**. The operator based on *Hermite interpolation* method will be revised in order to cope with non-circular geometry (polar system is used for the moment in Gysela). We want to describe and address a poloidal plane on a more flexible basis in order to describe D-shaped plasma (triangularity, elongation) in the Gysela code.

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