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PROPOSITION DE SUJET DE THÈSE 2011

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Titre du sujet de thèse : Peta and exascale algorithms for turbulence simulation of fusion plasmas

Résumé du sujet : Significant recent progress in simulations of fine-scale turbulence and in large-scale dynamics of magnetically confined plasmas has been enabled by access to terascale supercomputers. These progress would have been unreachable without innovative analytic and computational methods for developing reduced descriptions of physics phenomena. In particular, the plasma science community has developed advanced codes for which computer runtime scales quite well with the number of processors up to thousands cores. Accelerated progress on this critical issue is especially important for ITER, because the size and cost of a fusion reactor are determined by the balance between 1) loss processes and 2) self-heating rates of the actual fusion reactions. Realistic models, simulations and highly parallel algorithms are essential in dealing with such challenges because of the huge range of temporal and spatial scales involved.

A good example of these scalable tool is the GYSELA code, developed at CEA Cadarache. A realistic physics case has used 8192 processors during one month (june 2010) to produce a 5D nonlinear simulation. That kind of simulation enhances scientific understanding of the nature of plasma turbulence in fusion plasmas. The performed calculations typically involve meshes with billions of grid points and thousands of time steps. The GYSELA code uses a scalable parallelization on todays supercomputers using mixed mode MPI+OpenMP programming. This tool scales to 8192 processors with better thant 80% efficiency.

As clock frequencies of CPUs stalled in 2002, future petascale and exascale machines are expected to be different to current supercomputers. Some of the characteristics of these new machines are: hundreds of many cores per chip, less memory and bandwidth available per core, billions of cores per machine, frequent hardware failures. These new characteristics of supercomputers require a major shift from today's software infrastructure. The main goal of the proposed work is to overhaul the GYSELA code in order to be able to use these new machines:

1. Multilevel parallel algorithms must be designed to cope with high numbers of cores.
2. Higher core per chip induces that we have to extract very fine-grained parallelism.
3. With less available memory per core, data-structure of today's simulation tools must be changed.
4. We will also need innovative compressed data export and visualization methods to deal with increasingly huge amounts of data generated by simulations.

Programming techniques and algorithmic studies conducted during this PhD will be useful for the HPC (High Performance Computing) community. Achieving simulation on exascale devices constitute a big challenge and we actually do not know how to scale and tune applications to this aim.

Compétences souhaitées : Parallel computing

Intitulé du M2 préconisé : Computer science