C2S@Exa Inria Project Lab (IPL)
Computer and computational sciences at exascale

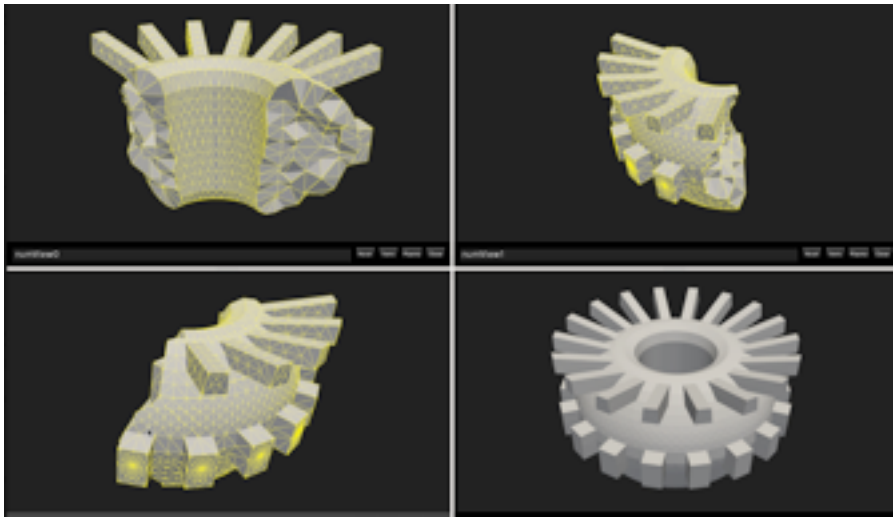
Technical meeting
Meshes and their use in large-scale simulations
Institute Henri Poincaré
May 14, 2013

Location: Institute Henri Poincaré (IHP), 1 rue Pierre et Marie Curie - 75231 Paris Cedex 05

Access: http://www.ihp.fr/en/ihp/acces

It is nowadays recognized that a multidisciplinary approach is required to overcome the challenges raised by the development of highly scalable numerical simulation software that can exploit computing platforms offering several hundreds of thousands of cores. To achieve this goal, the C2S@Exa IPL gathers (a) computer scientists that study programming models, and develop environments and tools for harnessing massively parallel systems, (b) algorithmicists that devise numerical kernels and core solvers, and develop generic libraries in order to take benefit from all the parallelism levels with the main goal of optimal scaling on very large numbers of computing entities and, (3) numerical mathematicians that are studying numerical schemes and develop parallel solvers for systems of partial differential equations in view of the simulation of complex physical problems. Based on this continuum of expertise, research and development activities conducted in the C2S@Exa IPL aim at the development of high performance numerical modeling methodologies that fully exploit the processing capabilities of modern massively parallel architectures in the context of a number of selected applications related to important scientific and technological challenges for the quality and the security of life in our society. For each of the considered application domains, associated use cases have been defined in conjunction with external partners for the demonstration of the possibilities of the high performance numerical modeling methodologies that are developed in the project. The two external partners currently involved in the project are ANDRA (French National Agency for Radioactive Waste Management) and CEA-IRFM (French Alternative Energies and Atomic Energy Commission).

The numerical methodologies for the simulation of the physical problems underlying the uses cases considered in the C2S@Exa IPL rely on finite element or finite volume schemes that are formulated on hexahedral or tetrahedral unstructured meshes. Mesh related operations such as mesh generation, mesh adaptation, mesh partitioning and re-partitioning, are central topics to these numerical simulations as it is the case for other applications of the computational sciences. This one day meeting will be allow to present ongoing research activities at Inria that aim at producing strategies and tools for manipulating very large meshes in the context of large scale parallel simulations.



Nabil Birgle, POMDAPI project-team
Cécile Dobrzynski, BACCHUS project-team
Philippe Helluy, TONUS project-team
Nassim Jibai, NACHOS project-team
Rachid El Khaoulani, NACHOS project-team
Paul-Louis George, GAMMA3 project-team
Luc Giraud, HIEPACS project-team
Clément Jamin, *GEOMETRICA project-team*
Cédric Lachat, BACCHUS project-team
Grégoire Lecourt, SAGE project-team
Bruno Lévy, ALICE project-team
Stéphane Lanteri, NACHOS project-team
François Pellegrini, BACCHUS project-team
Jean Roger, ANDRA
Jean Roman, HIEPACS project-team
Mariette Yvinec, *GEOMETRICA project-team*

Preliminary program

9h00-10h00 Welcome of the participants

10h00 - 10h20
Stéphane Lanteri, NACHOS project-team
C2S@Exa – An INRIA Project Lab on high performance computing for computational sciences

10h20 – 10h50
Clément Jamin and Mariette Yvinette, GEOMETRICA project-team
CGALmesh
CGALmesh is a simplicial mesh generator developed in the framework of the library CGAL (Computational Geometry Algorithm Library). This mesh generator combines a Delaunay refinement process with smoothing optimization operations. The refinement process is based on the notion of restricted Delaunay triangulations, which results in the capacity to mesh in a single process complex multi-labelled domains together with their boundary and subdividing surfaces. The generator may handle smooth or piecewise smooth surfaces and 3D domains bounded by such surfaces. A careful software design provides a high flexibility with respect to input domain representations. Current work includes the development of a parallel version of CGALmesh and the generation of anisotropic meshes.

10h50 – 11h20
François Pellegrini, BACCHUS project-team
The PaMPA tool for parallel mesh partitioning and adaptation
This talk will present the structure and operations of PaMPA (Parallel Mesh Partitioning and Adaptation), a middleware library dedicated to the management of unstructured meshes distributed across the processors of a parallel machine. Its purpose is to relieve solver writers from the tedious and error prone task of writing again and again service routines for mesh handling, data communication and exchange, remeshing, and data redistribution.

11h20 – 11h50
Cécile Dobrzynski, BACCHUS project-team
MMG3D : remailleur iso/aniso de maillage en tétraèdres
L'objectif de cet exposé est de présenter le logiciel MMG3D, remailleur tétraédrique basé sur des modifications locales et permettant la génération de maillages adaptés tant dans le volume que sur la surface. Partant d'un maillage en tétraèdres, nous reconstruisons un modèle de surface basé sur la triangulation initiale et représenté par des triangles de Bézier de degré 3. Le maillage de surface est ensuite modifié en contrôlant la distance de Haussdorf à ce modèle. Tout au long du processus de maillage, les points sont insérés via un inserteur de Delaunay anisotrope ainsi que des découpages d'éléments et le maillage est modifié itérativement, garantissant ainsi d'obtenir toujours un maillage valide. Des exemples d'adaptation isotrope et anisotrope viendront illustrer l'exposé.

11h50 – 12h20
Jean Roger, ANDRA
La problématique des maillages pour la simulation numérique des stockages de déchets radioactifs
Les maillages utilisés dans les simulations conduites par l'Andra aux différentes échelles spatiales d'un stockage et de son environnement géologique doivent permettre d'accéder à la compréhension phénoménologique fine du système et de son évolution sur de grandes échelles de temps, afin de répondre aux besoins précis de la conception et des évaluations de performance/sûreté des stockages. La fidélité et la finesse de la représentation géométrique du milieu géologique et des différents ouvrages du stockage sont essentielles pour atteindre cet objectif, en lien étroit avec les méthodes de résolution des modèles mathématiques des phénomènes simulés et les caractéristiques des calculateurs. Depuis de nombreuses années, l'Andra a engagé des actions de R&D pour explorer, valider et mettre en œuvre des techniques de maillage suivant deux axes : (i) l'accroissement de la taille des maillages, et l'utilisation des maillages mixtes et (ii) des maillages adaptés et adaptables en espace et en temps. L'objet de l'exposé est de présenter la problématique, les besoins, ainsi que les travaux de R&D qui ont été menés, illustrés sur quelques exemples.

12h20 – 14h00 Lunch

14h00 – 14h30
Bruno Lévy, ALICE project-team
Parallel meshing by enumerating the vertices of Voronoi cells
This presentation deals with mesh generation and surface reconstruction from scattered point sets. We focus on computing the Voronoi diagram of a point set (or its restriction to certain geometrical objects), that plays a central role for a whole class of algorithms. Thanks to a simple geometrical characterization of the (restricted) Voronoi cells, it is possible to avoid certain inter-dependencies in the computations. This geometric characterization naturally leads to parallel and scalable versions of these algorithms. Moreover, except from nearest neighbors search, all the computations are independent on the dimension of the embedding space (they solely depend on the metric, i.e. on the dot product in this space). For instance, it makes it possible to generate an

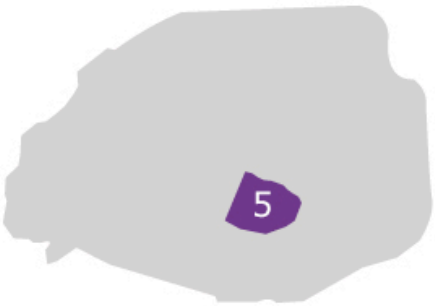
anisotropic surface mesh, considered as a higher-dimensional isotropic surface mesh, projected onto the 3d space. In other words, "anisotropy is traded for additional dimensions".

14h30 – 15h00
Paul-Louis George, GAMMA3 project-team
Remarques sur les grands maillages, comment les construire et/ou comment les éviter

15h00 – 15h30
Philippe Helluy, TONUS project-team
Meshes for TONUS
In this talk, we will describe rapidly the activity of the TONUS project0-team on numerical simulations for plasma physics with a particular emphasis on mesh data structures used in the CLAC and Selalib libraries.

15h30 – 17h00 Discussion

17h00 End of the meeting



Bienvenue dans le Vème arrondissement de Paris