Proposal for a PhD. Thesis in Computer Science.

Subject: Numerical simulations of incompressible fluid flows on heterogeneous parallel architectures.

Scientific context and subject description: The advent of new processor architectures (e.g. multicore, GPUs) requires the rethinking of most of the scientific applications and innovative methods must be proposed in order to take full advantage of current supercomputers. Recent efforts have been made by the high-performance computing community in adapting numerical linear algebra libraries and we propose to extend these adaptations to iterative solvers used for solving large sparse linear systems (Krylov or multigrid methods) with application to computational fluid mechanics.

The work proposed here will focus on the solution of large sparse linear systems coming from the discretization of Helmholtz and Poisson equations that represent the major part of the computational time for solving the Navier-Stokes equations describing a large class of fluid flows. The algorithms must take advantage of the current heterogeneous multicore/GPU architectures and minimize the amount of communication in the linear algebra kernels involved in the computation (e.g. sparse matrix-vector product [1]) and in the choice of the preconditioners. They need to be based on hybrid programming techniques (see e.g. [2]) that adapt the task granularity to the component that executes the task. They also require the use of advanced scheduling techniques to minimize the number of synchronizations during the execution. The algorithms developed during this PhD thesis will be validated on physical applications studied at LIMSI (`http://www.limsi.fr`) in the area of numerical simulations of incompressible flows -see [3] for an example of application-, the criteria for this evaluation being based on accuracy and performance.

This PhD thesis will take part in a multidisciplinary collaboration between researchers from University Paris-Sud, INRIA-Saclay and LIMSI/CNRS in the framework of the CALIFHA project. The nature of this thesis which handles innovative parallel algorithms as well as CFD numerical simulations should enable us to publish our results in both computer science and applied physics journals. The software developed during this thesis should be part of a reference public domain library.

Advisors:
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Practical details: This is a three years PhD studentship funded by Region Île-de-France and Digitéo (`http://www.digiteo.fr`). It includes a monthly salary after taxes of around 1500 € (medical insurance included) with coverage of travel expenses to attend conferences. The position is expected to start in October 2011. The student will be enrolled in the Department of Computer Science at University Paris-Sud (Orsay, France) and will be based at LRI (`http://www.lri.fr`), located on "Plateau de Saclay", which concentrates many prestigious research institutions, 25 km south of Paris.

How to apply: Applicants must have a Master degree in Applied Mathematics, Computer Science or other relevant field. Good programming skills are required. Experience with iterative linear algebra solvers is a plus. Applicants should email a CV and contact information of two references to `marc.baboulin@inria.fr` by Friday July 8, 2011.

References

[1] N. Bell, M. Garland,
Implementing sparse matrix-vector multiplication on throughput-oriented processors. *SC '09: Proceedings of the Conference on High Performance Computing Networking, Storage and Analysis, ACM, pp. 1-11 (2009).*

[2] S. Tomov, J. Dongarra, M. Baboulin,
Towards dense linear algebra for hybrid GPU accelerated manycore systems, *Parallel Computing*, Vol. 36, No 5&6, pp. 232-240 (2010).

[3] B. Podvin, Y. Fraigneau, F. Lusseyran, P. Gougat
A reconstruction method for the flow past an open cavity, *J. Fluids Engineerings*, Vol. 128, pp. 531-540 (2006).