Post-doctoral proposal:

Precision auto-tuning and numerical validation of high performance simulations

Background

This PostDoc will be carried out in the framework of the PEPR (Programme et Équipement Prioritaire de Recherche) NumPEx project[1] devoted to High Performance Numerics for the Exascale and financed by the France2030 investment program.

Nowadays, most numerical simulations are performed in IEEE754 binary64 precision (double precision) [3]. But this approach can be costly in terms of computing time, memory transfer and energy consumption. A better strategy would be to use no more precision than needed to get the desired accuracy on the computed result. The challenge of using mixed precision is to find which variables may be represented in lower precision (such as single or half precision) and which ones should stay in higher precision (double precision).

Several precision auto-tuning tools, such as FloatSmith [5], Precimonious [6] and PROMISE [2, 4, 1], have been proposed. From an initial user program, PROMISE[2] (PRecision OptiMISEd) automatically modifies the precision of variables taking into account an accuracy requirement on the computed results. To estimate the numerical quality of results, PROMISE uses Discrete Stochastic Arithmetic (DSA) [7] that controls round-off errors in simulation programs. The search for a suitable precision configuration is performed with a reasonable complexity thanks to the Delta Debug algorithm [8] based on a hypothesis-trial-result loop.

Research directions

During this PostDoc several directions will be explored to improve algorithms for precision auto-tuning and numerical validation.

[1] `http://numpex.fr`
[2] `http://promise.lip6.fr`

We plan to design a novel autotuning algorithm that will automatically provide arbitrary precision codes, from a required accuracy on the computed results. Because of the number of possible type configurations, particular attention will be paid to the algorithm performance. The type configuration produced will then enable one to improve storage cost, and also execution time taking into account the numerical formats available on the target architectures.

We plan to combine mixed precision algorithms and precision autotuning tools. Such automatic tools may be useful in the design of mixed precision linear algebra algorithms. Conversely the performance of precision autotuning tools may be improved thanks to mixed precision algorithms. Linear algebra kernels could be automatically identified in simulation codes, and replaced by their mixed precision version, in order to reduce the exploration space for precision tuning.

The precision auto-tuning algorithms designed during this PostDoc will be validated on large scale programs developed by partners of the NumPEx project. Furthermore new methodologies will be proposed to perform autotuning of both numerical formats and performance parameters in collaboration with experts in coupled physics simulations.

Location

Sorbonne Université and its Computer Science lab LIP6 are settled on the Pierre & Marie Curie Campus in the Latin Quarter of Paris, France.

Salary

The gross salary per month (including national health insurance and employment insurance) varies from 2682 to 3701 euros depending on the experience.

Duration

1 year, renewable 1 year

Qualifications and skills

Candidates must have a PhD in Computer Science, Applied Mathematics or other relevant fields, with good programming skills. Developments will be carried out in C++ and Python, so programming expertise in at least one of these languages is required. Good knowledge in numerical algorithms and floating-point computation is also required.

Application

Applications should be sent to Fabienne Jézéquel (`Fabienne.Jezequel@lip6.fr`). They should include:

- a curriculum vitae;
- a motivation letter;
- at least two referees with their e-mail addresses;
- links to PhD thesis and publications;
- links to software contributions.

References

[1] Quentin Ferro, Stef Graillat, Thibault Hilaire, Fabienne Jézéquel, and Basile Lewandowski. Neural Network Precision Tuning Using Stochastic Arithmetic. In *NSV'22, 15th International Workshop on Numerical Software Verification,*, Haifa, Israel, August 2022.

[2] S. Graillat, F. Jézéquel, R. Picot, F. Févotte, and B. Lathuilière. Auto-tuning for floating-point precision with discrete stochastic arithmetic. *Journal of Computational Science*, 36:101017, 2019.

[3] IEEE Computer Society. *IEEE Standard for Floating-Point Arithmetic.* IEEE Standard 754-2008, August 2008.

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[5] M. O. Lam, T. Vanderbruggen, H. Menon, and M. Schordan. Tool integration for source-level mixed precision. In *2019 IEEE/ACM 3rd International Workshop on Software Correctness for HPC Applications (Correctness)*, pages 27–35, 2019.

[6] Cindy Rubio-González, Cuong Nguyen, Hong Diep Nguyen, James Demmel, William Kahan, Koushik Sen, David H. Bailey, Costin Iancu, and David Hough. Precimonious: Tuning assistant for floating-point precision. In *Proceedings of the International Conference on High Performance Computing, Networking, Storage and Analysis*, SC'13, pages 27:1–27:12, New York, NY, USA, 2013. ACM.

[7] J. Vignes. Discrete Stochastic Arithmetic for validating results of numerical software. *Numerical Algorithms*, 37(1–4):377–390, December 2004.

[8] Andreas Zeller. *Why Programs Fail.* Morgan Kaufmann, Boston, second edition, 2009.